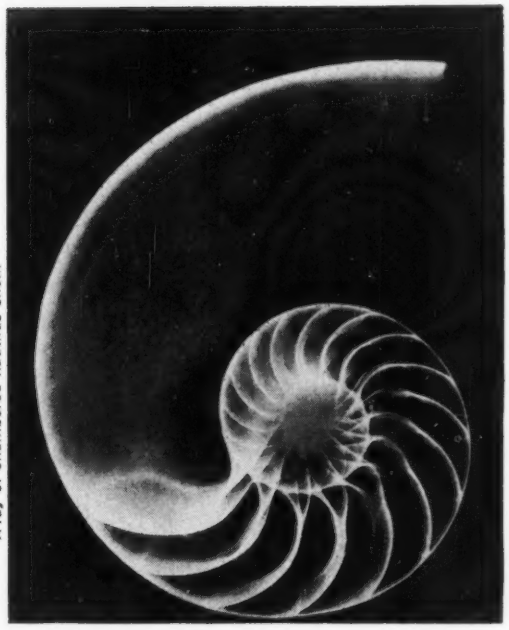
SCHOLASTIC TEACHER EDITION OF SCIENCE WORLD II / VOL. 8, NO. 1, / SEPT. 14, 1960

grades 10, 11, 12



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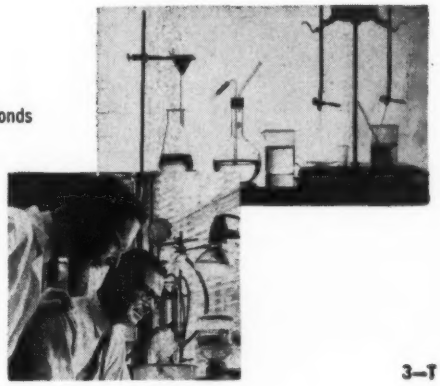

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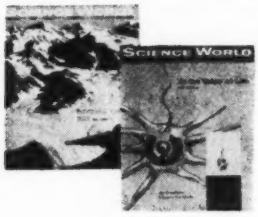

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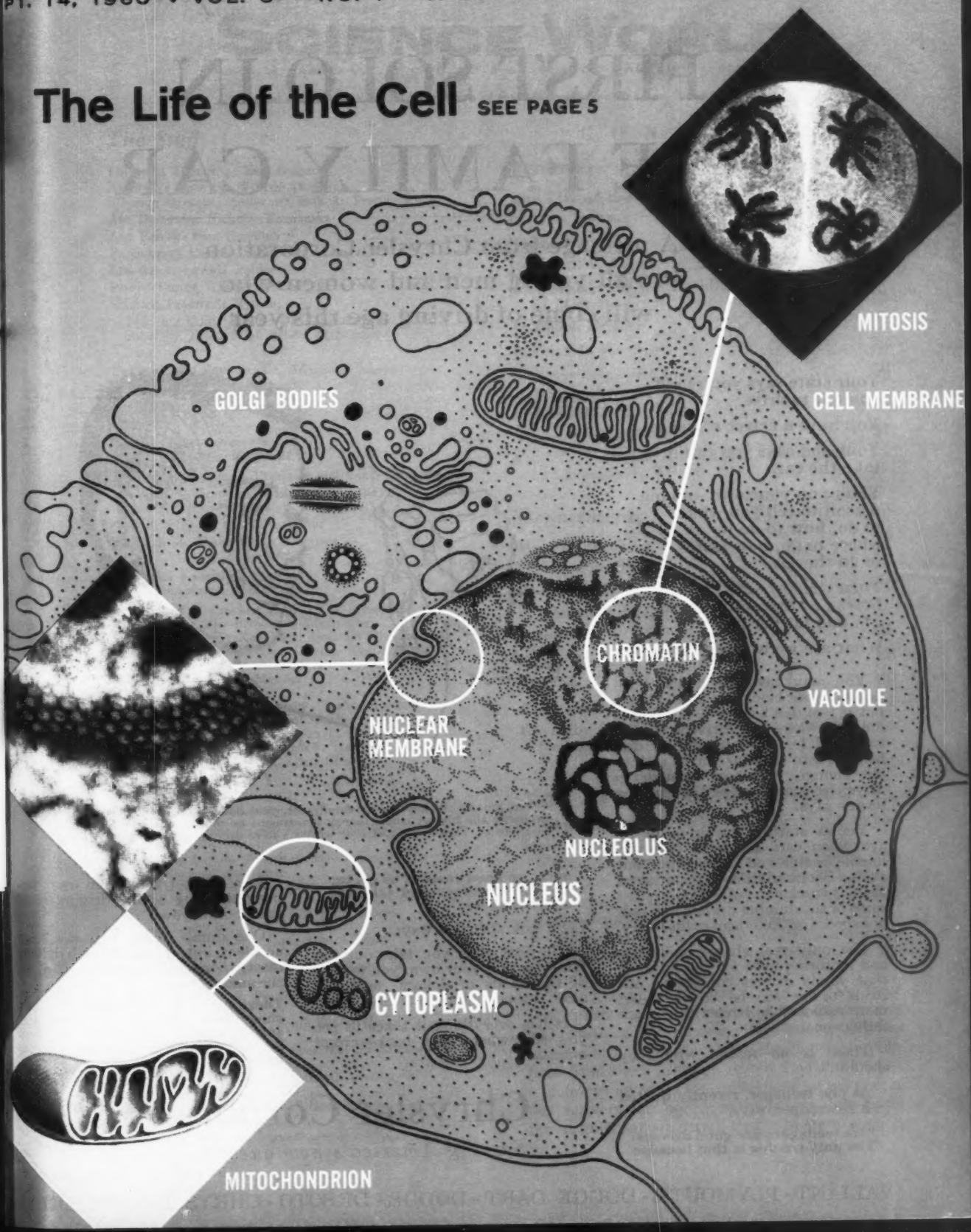
SCIENCE WORLD

PT. 14, 1960 • VOL. 8 • NO. 1 • A SCHOLASTIC MAGAZINE • EDITION II

The Life of the Cell

SEE PAGE 5



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SCIENCE WORLD

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CONTENTS

Features

The Life of the Cell 5
by Isaac Asimov

Tsunami 9
by Robert C. Cowen

The Search for the Building Blocks of Matter 13
by Simon Dresner

Science in the News 18

Today's Scientists 20
Dr. Herbert Friedman
Rocket Astronomer

Tomorrow's Scientists 21
Projects by Stephen Hubbell and Thomas Pliske, and Franklin F. Wilcox

Departments

Meeting the Test 17
by Theodore Benjamin

Project Pointers 25
by Alexander Joseph

Letters 26

Brain Teasers 28

Sci-Fun 30

Crossword Puzzle 31

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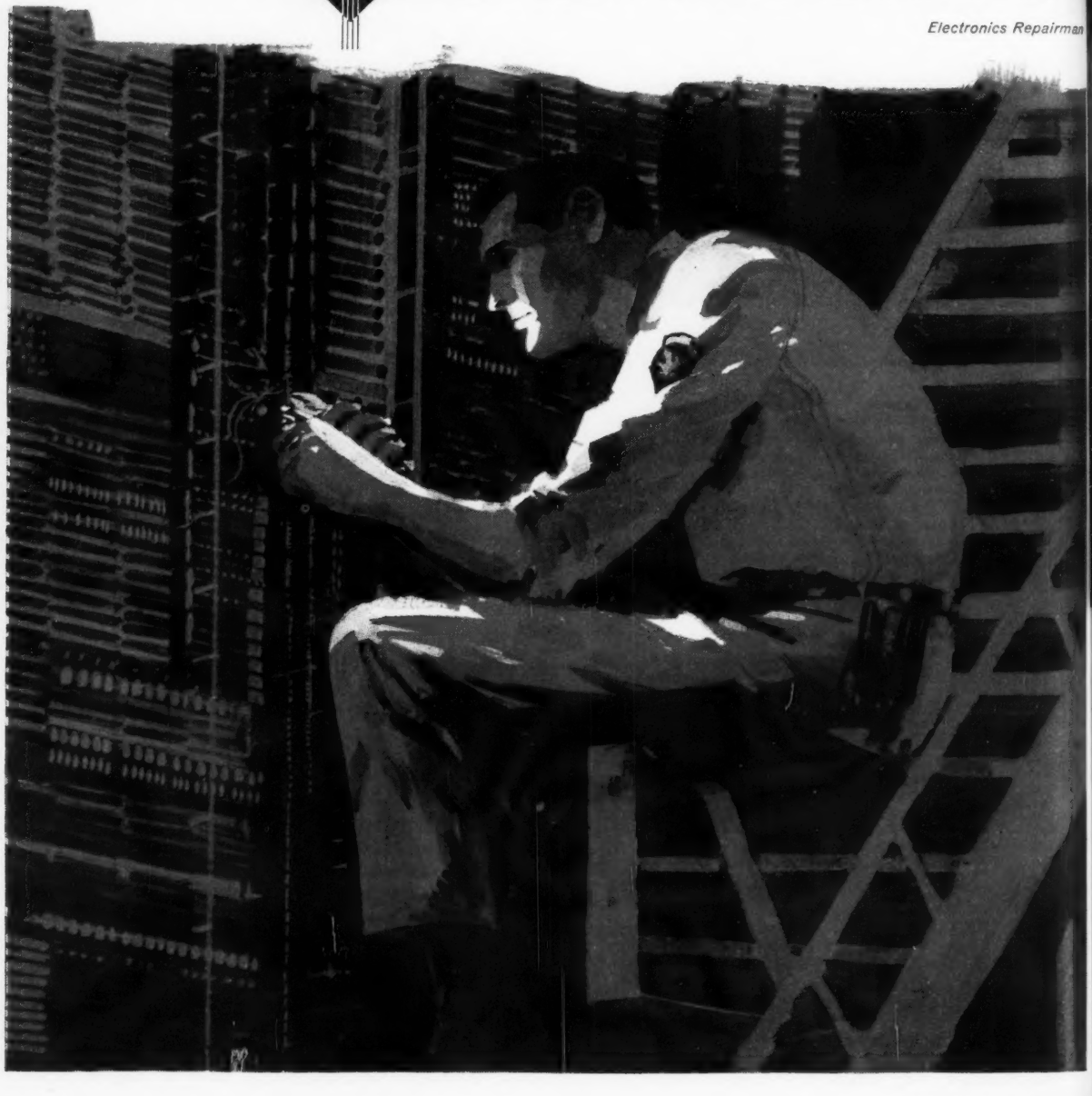
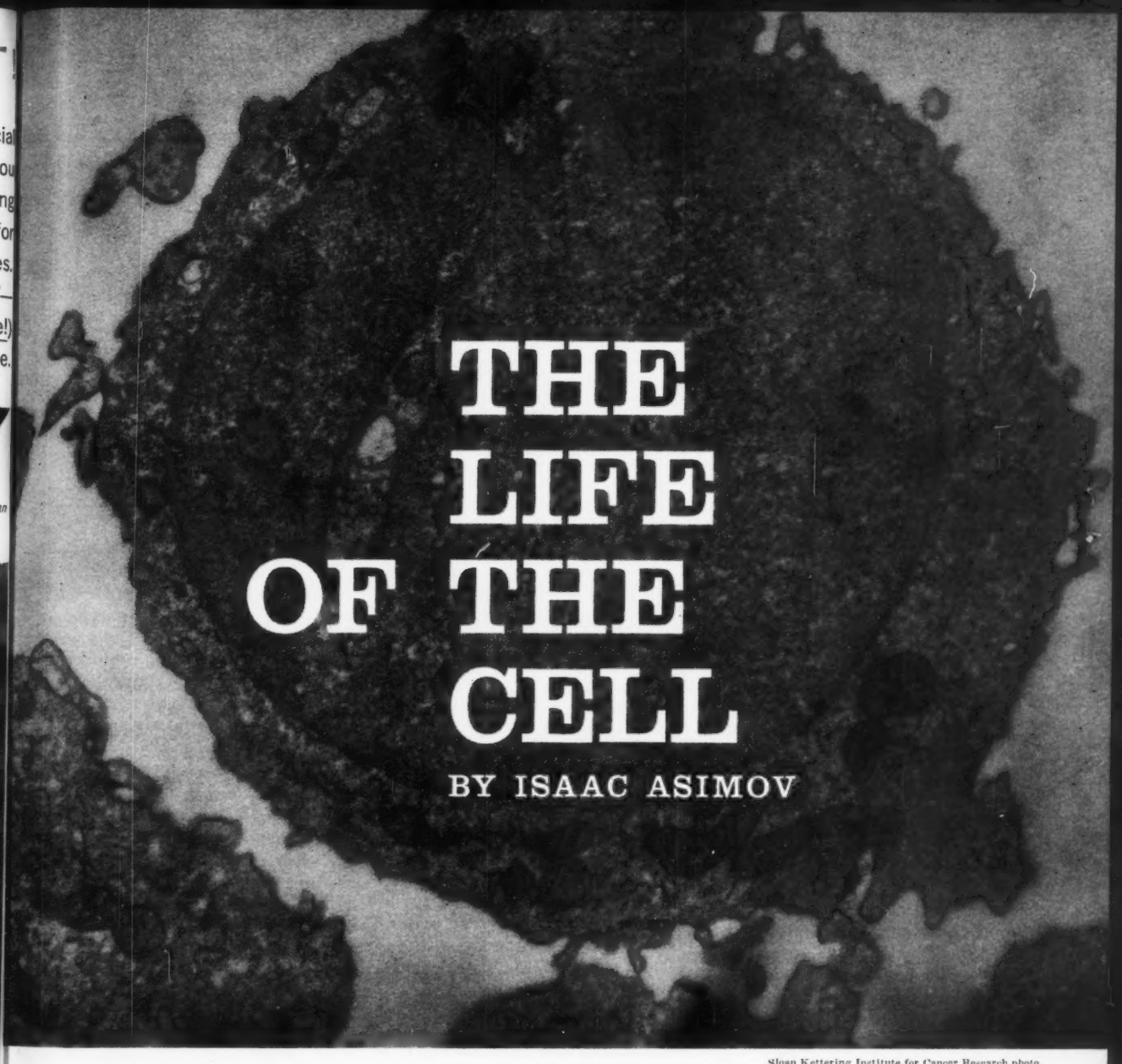




THE LIFE OF THE CELL

BY ISAAC ASIMOV

Sloan Kettering Institute for Cancer Research photo

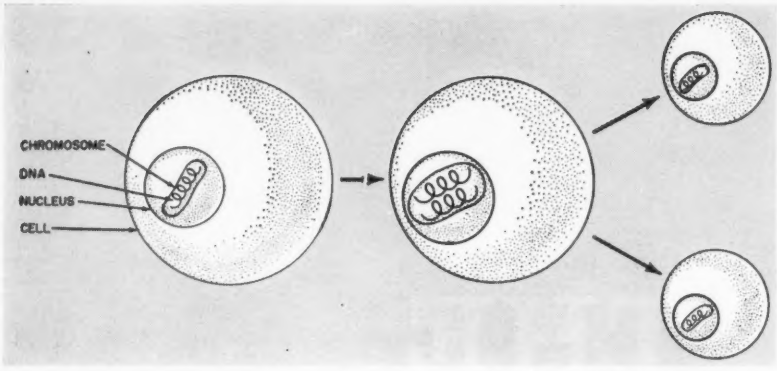
We are learning more and more about the cell, the basic unit of life and the source of life's energy

BIOLOGY is the science of life. But what is life? There is no satisfactory definition. But scientists know a great deal about life even though they can't define it. The basic unit of life is the cell. And it is energy that links the cell to all the processes of life. Birth, growth, development, behavior, reproduction, death—the processes most typical of living organisms—all involve energy transformation.

The source of life's energy is found in the chemical activity of living cells. In a sense, cells may be thought of as microscopic chemical factories. Their product—life.

A bird's wing, the tail of a fish, an elephant's trunk, the petals of a flower—all are composed of cells. When you were born your body contained an estimated two thousand billion cells and, when your growth has stopped, it may contain as many as sixty thousand billion cells. Many of the cells in your body and the bodies of other organisms—both plant and animal—seem to be adapted to carry out specific functions. Blood cells are different in appearance and function from bone cells. These, in turn, are different from nerve cells.

It is obvious that there is no typical cell. However, at some time during their lives all cells have a typical structure. Each cell has a membrane that separates it from its neighbors and the fluids that bathe it. When a cell is stained with dye its structure becomes visible. Most prominent is the *nucleus*. Around the nu-



Sloan Kettering Institute for Cancer Research

Sausage shaped chromosomes in cell diagram above are rich in DNA. At the time of cell division, DNA molecule first doubles and then divides. Thus when cell divides, each daughter cell receives an amount of DNA equal to that in parent cell.

cleus there is a body of complex liquid material, called the *cytoplasm*. But it is best to think of nucleus, cytoplasm, and membrane as the locations of specific activities, as well as structures, for each contains smaller structures called *organelles* (little organs).

The main features of the cell were known sixty or more years ago. Observations with light microscopes and experiments with cells suggested that structure and function were related. Each part of the cell, it was thought, had specific functions.

The question that *cytologists* (scientists who study cells) are now seeking to answer is this—how do the various parts of the cell carry on their activities? Armed with new tools—the electron microscope, which can form images of objects as small as a millionth of a millimeter, high speed centrifuges to separate cell constituents, and new *microsurgical* and chemical techniques—biologists and biochemists are attacking the problem. They are seeking a new and deeper understanding of the tiny living "chemical factory."

Nucleus—the Key

It is the nucleus that is thought to control the cell's activities. Dr. Carl Swanson of The Johns Hopkins University in Baltimore, Maryland, calls it "the board of directors of the cellular factory."

Sometimes, particularly when cells divide to form new cells, corkscrew-shaped bodies are visible within the nucleus. The bodies are called chromosomes. These, too, are complex structures. Like every other part of our bodies, chromosomes are made of a mixture of chemical compounds. Among other substances, they contain relatively large amounts of a chemical called deoxyribonucleic acid (DNA for short). It is found practically nowhere else in the cell.

Chemical and experimental evidence suggests that DNA controls heredity.

A short chemical "excursion" will be helpful in understanding DNA. We can tell one chemical compound from another because each is always made of a definite number of certain kinds of atoms which give the compound its characteristics. The smallest recognizable amount of a compound having these characteristics is called a *molecule*. Many of the compounds found in living organisms and their cells have thousands of atoms. In such compounds the arrangement of atoms is important. It is this arrangement that gives to molecules their shape.

DNA appears to be the key component of each chromosome. When analyzed, DNA has been found to consist of four smaller chemical units. These smaller units can be arranged in an extremely large number of ways, all of which have similar chemical characteristics and the shape of the DNA molecule. Thus, there are many possible variations of the DNA molecule, each with its own pattern. There is good evidence that DNA is the major chemical of heredity. According to a current theory, DNA serves as a pattern for the other cellular substances.

This is how it seems to function.

DNA molecules are large enough to be studied with the electron microscope. They appear to be coiled, like a spring or helix. The DNA molecule is sometimes compared to a spiral staircase, with one kind of chemical forming the bannisters and the others forming the treads. More DNA is made when the components split into two spirals. Each serves as the model for the construction of a new partner. This process is called *replication*, and in the end two molecules exist where there was only one.

Two From One

As an organism grows and develops from a single cell, its cells divide and duplicate themselves. At the end of this type of cell division, called *mitosis*, there are two cells, each with a complete set of chromosomes. It seems evident that the process by which one DNA molecule replicates itself has a function in the replication of chromosomes. Consequently, each new cell inherits the chemical pattern of the original.

The nucleus of a cell is heavier than an equal volume of cytoplasm. Thus the nucleus can be separated from cells by centrifuging them, in much the same way that water is separated

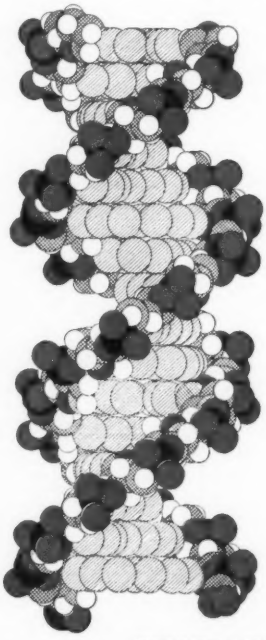
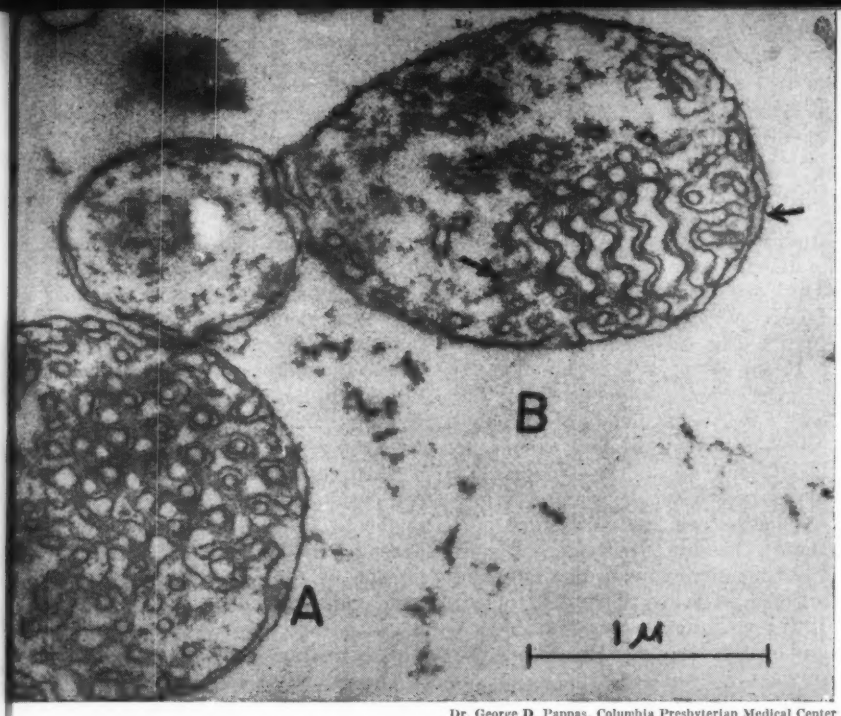


Diagram from L. D. Hamilton

Diagram shows spiral structure of DNA.



Dr. George D. Pappas, Columbia Presbyterian Medical Center

Electron micrograph shows mitochondria of amoeba, *Chaos chaos*, enlarged 37,000 times. Folds of membrane may increase surface area for energy production in cell.

from clothes in a spin-dryer. It is possible, then, for biologists to obtain the DNA for study.

A famous experiment that has now become a classic of DNA research is one of the strongest clues in the chain of evidence linking DNA to heredity. There are many types of pneumococcus – the organism that causes pneumonia. Some are surrounded by a smooth capsule. These are particularly *virulent* (dangerous). Others appear rough and lack the capsule. They are less virulent. When DNA is removed from the smooth kind, purified, and added to a solution containing rough cells, an interesting change occurs. Smooth capsule-covered, virulent organisms occur where there were none before. These new cells are rough cells that have apparently absorbed the smooth type of DNA. And these newly virulent cells can transmit their characteristics.

Cells Made to Order

In the past year, two Harvard scientists, Dr. Paul Doty and Dr. Julius Marmur, have added still more evidence. They have found that gentle heating of isolated DNA molecules reduces their molecular weight (the sum of the weights of the atoms that comprise the molecule) by half. A plausible explanation is that the double coils have been jostled apart by heat into single strands, just as they might be in natural cell division. They also found that if the mixture is cooled slowly, the strands re-combine into double coils—but not always in the original combination.

The Harvard scientists separated the DNA from two different but related types of bacteria. Then they mixed it, heated it, and let it cool. This was their hypothesis—when the single strands of DNA recombined to form double coils, some would contain a strand from each type of bacteria. Thus, when introduced into colonies of living bacteria, the newly formed combinations would produce bacterial cells that had a combination of characteristics from the two original types. Experiment confirmed their hypothesis.

The work of Dr. Doty and Dr. Marmur not only gives further support to the theory that the chromosomes control heredity; it suggests something far more exciting. We may be able some day to "design" cells to fit particular needs. Some day, man may be able to control heredity.

There is still another problem. How does the nucleus control the cytoplasm (the cellular region outside the nucleus), where most of the chemical activity of the cell takes place?

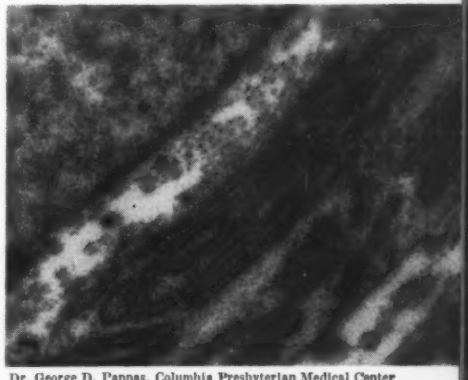
In the cytoplasm there is ribonucleic acid (RNA). While the chromosomes are composed mainly of deoxyribonucleic acid (DNA), they also contain a small amount of RNA. Current theory suggests that the DNA serves as a pattern for the preparation of specific molecules of RNA. According to the theory, these RNA molecules made in the nucleus are stored in the *nucleolus*.

How is the RNA stored in the nucleolus transferred across the barrier of the nuclear membrane into the cytoplasm? For a long time scientists thought that this took place during cell division. At that time, the nuclear membrane temporarily breaks down and the material within the nucleus mixes with the cytoplasm.

Barrier That Isn't There

Using an electron microscope, Dr. Helen Gay and others at the Carnegie Foundation at Cold Spring Harbor, New York, found that the nuclear membrane is not a barrier. Instead, it is highly porous. The transfer of material actually takes place at all stages of cellular existence. Materials produced in the nucleus approach a portion of the nuclear membrane, which then "bellies" outward in tiny blisters. Material pours through the blisters into the cytoplasm, forming minute bubbles or "blebs." Thus, it turns out that the nucleus is not isolated by its membrane. It is in intimate contact with the cytoplasm at all times.

With the light microscope, the cytoplasm appears to be a semi-thick fluid. This appearance is deceiving.



Dr. George D. Pappas, Columbia Presbyterian Medical Center

Electron micrograph of chick embryo cytoplasm shows endoplasmic reticulum. Cells may make proteins here. X 33,000.

The electron microscope shows that the cytoplasm contains a complex system of membranes—the *endoplasmic reticulum*. Lining these membranes and lying between their folds are many small bodies called *microsomes*. Chemical analysis shows them to be rich in RNA. Some cytologists think that the cell's proteins are produced in this system of membranes.

But all this activity—cell division, replication of DNA, and the manufacture of proteins—requires energy. Where is the source of the energy?

Within the cytoplasm are particles known as *mitochondria*. These are thought to supply the cell's energy. Mitochondria may take any shape, from spheres to rods, and appear to be in constant motion. The mitochondria can be seen with light microscopes. But Dr. George D. Pappas of Columbia University has studied their internal structure with the electron microscope. His studies reveal the inner structure of mitochondria to be complex.

"Powerhouse" of the Cell

For one thing, they have double membranes that form pouches within the body of the mitochondria. This results in a large surface for the available volume. Mitochondria can be separated from the rest of the cell by a centrifuge. Biochemists have found the membranes to be about 65 per cent protein and 35 per cent fat.

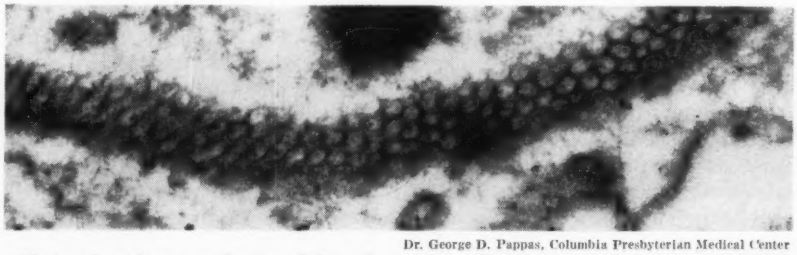
From the thickness of the double membrane (which appears to be the same in all cells of all organisms), it would seem that each half of the membrane is composed of a single layer of protein molecules backed by a single layer of fat molecules. The two halves join up fat sides together: protein-fat-fat-protein.

Dr. Albert L. Lehninger of The Johns Hopkins University, a cytologist, is particularly interested in how mitochondria carry on their function. He concentrates on their chemistry. The enzymes in the mitochondria apparently are involved in a whole series of chemical reactions which break down sugar. Ultimately, carbon dioxide and water are formed and energy is produced. The mitochondria might be thought of as the "powerhouses" of the cell. There, chemical reactions supply the energy for life processes. According to Dr. Lehninger, these conversions of sugar to carbon dioxide, water, and energy take place along the protein layer of the mitochondrial membrane.

Evidence accumulated in modern studies of cells shows that membranes are more than mere partitions. They are active participants in the life of the cell. In the mitochondrion particularly, the membrane appears to be the site of its basic function.

Even the membrane enclosing the entire cell is involved in an active roll. The cell or *plasma* membrane keeps some substances out of cells altogether, other substances firmly within the cell, and still other substances passing freely in and out. Electron microscope studies show the cell membrane to be intricately folded, with pouches extending into the cell and blisters bellying outward into the surrounding fluids.

Plant cells, however, and those of bacteria and yeasts, have thick outside walls in addition to cell membranes. What of these?



Dr. George D. Pappas, Columbia Presbyterian Medical Center

Photo of nuclear membrane of *Amoeba proteus* shows porous structure. X 19,000.

Bacteria, for instance, have cell walls that can be dissolved by a substance called *lysozyme*, which was originally discovered by Alexander Fleming (who discovered penicillin).

In 1953, a Swedish scientist, Dr. Claes Weibull, found how to dissolve the cell wall slowly with concentrations of lysozyme. Ordinarily, without its cell wall the bacterium would fall apart. Dr. Weibull found that if he used lysozyme in a dilute sugar solution, the bacterial cell stayed intact—as a bare membrane-covered cell called a *protoplast*.

Protoplasts can perform many—but not all—of the chemical tasks of bacteria with cell walls. Protoplasts can not form a new wall. They can grow, but cannot divide normally. Weibull's experiments suggest that the cell wall must be more than just a protective barrier.

In the case of yeast, the breakdown of a portion of the cell wall is a normal part of the life cycle. Yeast reproduces in a unique fashion. While most cells constrict down the middle and pinch into two equal portions, yeast cells form *buds*. Little bits of the cell substance belly out on some portion of the mother cell. The buds grow until they are nearly equal in size to the mother, then break away. Recent studies of the yeast cell wall show it to be made up largely of *cellulose* fibers.

At a particular stage of the yeast life cycle, the fibers in a particular region of the wall are broken, apparently by hydrogen atoms. This portion of the yeast wall weakens and, under pressure from the cytoplasm within, there is a "blowout." This is the bud.

The cell, small as it is, thus proves itself more and more with each passing year to be a complicated "chemical factory" filled with fascinating problems of the deepest significance to the science of life. Armed with new tools and new concepts, biologists and biochemists are attacking these problems to gain new depths of understanding.

But attacking problems is not the same as finding the answers. We all learn that in math. So, many of the things you have just read about the cell are not *facts*. They are *hypotheses*—educated guesses made on the best available evidence. For example, does DNA really serve as a pattern for the other substances in the cell? And if so, how? The answer to the first question is, "It seems reasonable." The answer to the second? "Nobody knows." But today our guesses are probably closer than they were a year ago.

And this is the way of science.

Next issue: Light and its influence on life.

The great seismic wave that smashes cities moves across the ocean at jet plane speed

By **ROBERT C. COWEN**

WHEN shock waves from the recent Chilean earthquakes reached the *seismic* (earthquake) observatory of the United States Coast and Geodetic Survey at Honolulu on May 23, the scientists suspected they had an emergency on their hands. Two and a half hours later they were sure of it. They flashed the first warning—a potentially destructive *tsunami*, a seismic or earthquake-caused "tidal wave," was on its way.

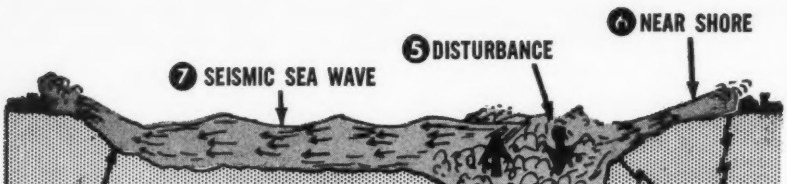
The people of the Hawaiian Islands were alerted to the emergency about five and a half hours before the first wave hit. Many lives were saved. Indeed, the scientists of the Survey believe even more lives could have been saved if more people had heeded the warnings to seek higher elevations. As evidence, there is the fact that no lives were lost in the tsunamis that struck in 1952 and 1957. The warnings had been strictly observed.

Such timely alerts are possible because Honolulu is the center of a tsunami warning system. This was set up after an especially destructive series of waves surprised the islands in April 1946. Reports come in from seismic and tidal observation stations throughout the Pacific. Seismologists and oceanographers at Honolulu use the reports to forecast seismic sea waves well in advance.

In Japanese, tsunami means "large waves in harbors." The popular name, "tidal wave," is descriptive, but it lacks scientific accuracy. Tsunamis have nothing to do with the normal rhythmical ebb and flow of sea and land surfaces we call tides.

Geophysicists (scientists who specialize in the Earth's structure and energy sources) are not entirely certain how tsunamis are caused. They seem to be involved with a process called faulting. In this process a part of the sea bed is dropped or raised suddenly, or blocks of the bed slide past one another horizontally. Some tsunamis apparently have been caused by gigantic submarine landslides and by volcanic eruptions. Any of these conceivably could release energy, to be transmitted through the water in waves. If the sea bed dropped, for example, water rushing in from the sides to fill the hole would converge and hump up at the surface, sending out waves in all directions.

Whatever the immediate cause, tsunamis are linked to the forces that give rise to earthquakes, from which they receive their energy. Preliminary analysis of data on the Chilean earthquakes indicates that energy



Science World graphic

Set in motion by earthquakes, tsunamis cross ocean at jet plane speeds. When tsunami hits shallow water its great energy is concentrated to produce waves of great force.

equivalent to 300 billion kilowatt-hours was released. This is equivalent to nearly half the amount of electricity generated by all the power plants of the United States in 1958. The small fraction of that energy transferred to the tsunami must have been enormous.

Today some geophysicists theorize that the energy deep within the Earth is heat energy released by radioactive atoms. To understand the relation between this heat energy and earthquakes and tsunamis, one needs to understand something of the structure of the Earth as a whole.

The Layers of the Earth

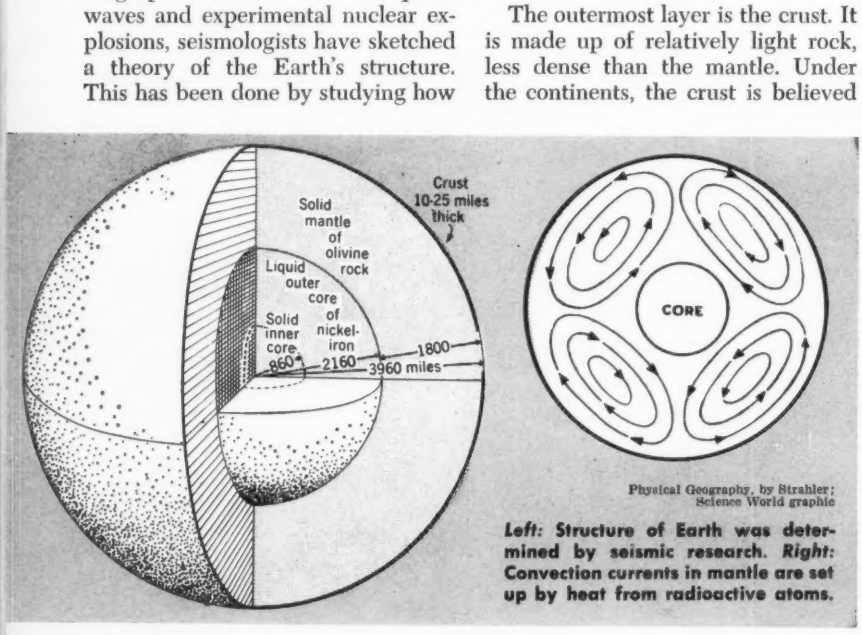
By recording and analyzing seismographic records of earthquake waves and experimental nuclear explosions, seismologists have sketched a theory of the Earth's structure. This has been done by studying how seismic waves are bent or reflected, speeded up or slowed down as they are propagated through the Earth.

Geophysicists now conceive the structure of the Earth as being made up of concentric layers, like a golf ball. Evidence suggests that the innermost layer is a very hot core, 2,160 miles in radius. This core is largely like a liquid or plastic in consistency, although wave behavior suggests there may be a solid inner core 860 miles in radius.

Surrounding the core is the spherical shell of the mantle, 1,800 miles thick. The mantle is more solid and rigid than steel, yet it is thought to flow like cold molasses under the pressure and stress of the powerful forces above and below.

The outermost layer is the crust. It is made up of relatively light rock, less dense than the mantle. Under the continents, the crust is believed to be 10 to 25 miles thick. Under the oceans, this crustal material thins to a mere three to eight miles.

Seismologists estimate the depth of the crust by measuring the velocity of shock waves as they travel through it. The denser the material, the faster the shock waves will travel. You may have observed that sound waves, which are similar to shock waves, travel faster in a steel bar than in air or water.



Physical Geography, by Strahler; Science World graphic

***Left:* Structure of Earth was determined by seismic research. *Right:* Convection currents in mantle are set up by heat from radioactive atoms.**

Probing the Moho

Almost everywhere geophysicists have probed, they have found a narrow region where the velocity of these waves increases rapidly, as they pass from the crust into the mantle. This indicates the presence of a thin boundary zone. It is the *Mohorovicic discontinuity,* or more simply the Moho. The National Academy of Sciences is sponsoring a project to drill through the Moho and penetrate the mantle. The Moho probe will give geophysicists their first direct sampling of this region. It will permit direct observations. These will support or disprove hypotheses based on indirect evidence.

According to one widely accepted current theory, the layered Earth began as a relatively low temperature mass. This mass condensed out of the same cloud of cosmic dust and gas that produced the sun. Heat from radioactive elements distributed through this mass then warmed it, causing it to melt, at least partially. As soon as melting began, there should have been a tendency for the lighter materials—and those with the lowest melting points—to float upwards. This would leave behind the heavier materials with a higher melting point. This hypothesis stems from the behavior of melting mixtures observed in laboratory and factory.

The radioactive materials have relatively low melting temperatures. Convection currents would carry them up until they were close to the surface. There, heat loss by conduction would be rapid. Temperatures would drop enough to prevent further melting. This is in accordance with the second law of heat. This law states that heat always flows from hot to cold.

The scientists who accept this

theory believe this process is still going on. Suppose a particular mass of such heat-producing material is not close enough to the surface to lose heat by conductive heat flow. If heat loss is blocked in some way, perhaps by an insulating layer of ocean bottom sediments, melting will occur locally. The energy released by the melting material will cause the material to move. Geologists are not at all certain, but they theorize that the enormous energies of earthquakes come from heat-producing radioactive materials in the mantle. These lead to the melting and movement of countless tons of rock.

One of the most active regions of energy release is along the rim of the Pacific Ocean basin. Here the Pacific is encircled by lines of volcanoes, earthquake zones, and deep ocean trenches. This is the Pacific's "ring of fire."

This is why most tsunamis, which seem to originate along the ocean trenches, are observed in the Pacific. Since 1819, some 40 such waves have been recorded in the Hawaiian Islands alone, where they may arrive from almost any part of the Pacific.

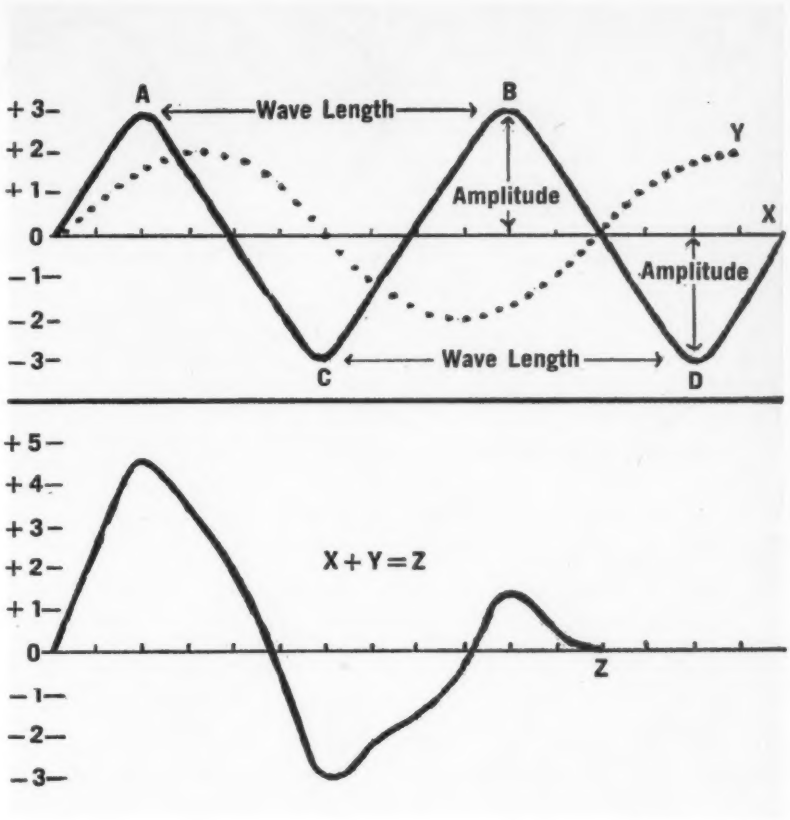
A tsunami sweeps over the ocean in much the same way as does a normal wind wave, with important differences. A close look at waves in general will help you understand these differences.

Crests and Troughs

A wave is not a solid thing. *It is a form or shape.* Energy passing through substances shapes them by moving in alternating surges—"peaks" and "lows." Thus we can say that energy travels or is propagated in waves.

A single wave is composed of a *crest* and a *trough*. The crest is the high point of the wave; the trough, the low point. In the case of water waves, a crest is the high point of the water above the normal water level.

The amount of energy in a wave is measured by its *amplitude*. This is the height of the crest or the depth of the trough of a wave—above or below mean (average) sea level. For example, if the crest or trough of an ocean wave is ten feet above or below the mean water level, its amplitude is ten feet.



Science World graphic

Top diagram shows two waves of different wave lengths and frequencies. Diagram at bottom shows how the two waves above may reinforce or cancel each other.

In water waves, the particles of water move up and down, perpendicular to the direction of the wave as it travels through the water. As the wave moves, the water particles move upward to the crest. When the crest moves forward, the particles *do not* move forward with it. They simply slip down to their normal level—and then further downward as the trough of the wave reaches them.

The distance between two crests or two troughs is the wave length. Wave lengths, however, are usually measured from one crest to the next.

In a series of waves, the individual waves move at a constant speed. The number of waves arriving at a point in a given unit of time varies with the wave length. This number is known as the frequency of the waves. The longer the wave length, the lower the frequency. However, if the wave crests are closer together, a greater number of waves will arrive in the same unit of time. The frequency will be higher.

The time it takes between the arrival of one crest and the next is called the period of the wave. High frequency short waves have short periods. Low frequency waves have longer periods.

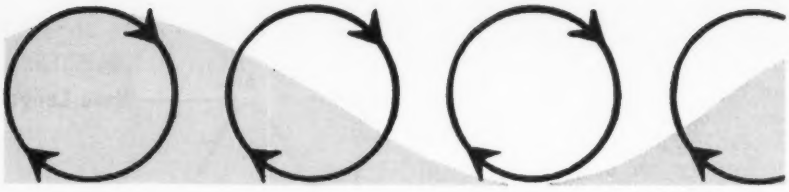
The wave lengths of ordinary ocean waves are normally only a few feet. Their periods are a matter of seconds. Tsunamis, on the other hand, have wave lengths of 100 to 650 miles. Their periods are as long as 15 minutes. Because of this, they can be thought of as a succession of isolated solitary waves, rather than as a train of waves. In fact, they are probably the nearest example found in nature to the ideal isolated wave with which theories deal.

Ocean Is Shallow to Tsunami

When a train of wind waves passes, the particles move in a circle or an ellipse—with no net forward movement (*see page* 12). You can see this when a floating bottle bobs up and down with the waves, but

does not move along with them. An isolated wave is different. Such a wave has only a crest. There is no trough. When the wave passes, water particles are moved forward a short distance and left there, as the wave goes on. The particles do not slip back. There is a net forward transport of water *which reaches to the bottom of the water mass.*

The depth of the ocean is important for waves of the seismic type. The velocity of the wave varies with the square root of the depth. The greater the depth, the greater the velocity.



Science World graphic

Water particles in wind waves, in contrast to tsunamis, do not move forward. Diagram shows particle moving in circle as it is lifted and dropped by crests and troughs.

As Fast as Jet Plane

Here is an important fundamental difference between an ordinary storm wave and a tsunami. With ordinary waves, the surface agitation extends only a few wave lengths down. The depth of the open ocean may be thousands of times greater than the wave length. But the two-and-a-half-mile average depth of the Pacific is a small fraction of the one-hundred-plus-mile wave length of a tsunami. For these great waves, it is a shallow ocean indeed. That is why the water movement associated with a tsunami may reach to the bottom.

Tsunamis race over the sea at jet plane speeds. In water 12,000 feet deep they travel at about 430 miles per hour. In 30,000-foot-water, they hit 650 mph.

If you were on a ship, you would scarcely notice these great waves as they sped by. In deep water their crests are only about two to seven feet high. But their tremendous energy is distributed throughout the entire mass of water from surface to bottom—at the point of passage. Then, as the bottom shoals near land, this energy is concentrated in an increasingly shallow mass of water. Thus a very large portion of this total energy can be released in a few minutes with destructive effect.

When a tsunami hits, successive incoming waves increase in height. Later waves may be more powerfully destructive than the first or second wave. As these waves drive against the shore, their destructive effect may be strengthened or diminished by offshore topography.

Waves coming in over offshore ridges tend to be exceptionally large. Here, again, the energy is being concentrated in a relatively much shallower mass of water. But barrier reefs can diminish the energy of the waves, dissipating it through friction.

In parts of Hawaii protected by wide reefs, tsunamis have risen only a foot or two, while nearby unprotected areas have been inundated and devastated by the sudden release of energy. Even the partial protection of a breakwater or sea wall is worthwhile.

Once started on their way, tsunamis can travel great distances with virtually undiminished energy. The waves that hit Hawaii last May went on to strike Japan more than 9,000 miles from their source in Chile. In the tsunami that hit Hawaii in 1946 some of the highest waves came 18 hours after the primary assault.

Dr. Francis P. Shepard, Professor of Submarine Geology at the Scripps Institution of Oceanography, La Jolla, Calif., was in Hawaii at that time. He has suggested that the late arriving waves had been reflected first from a submarine cliff off Japan and then from steep rock faces off Australia. It was analogous, he says, "to a three-cushion shot in billiards."

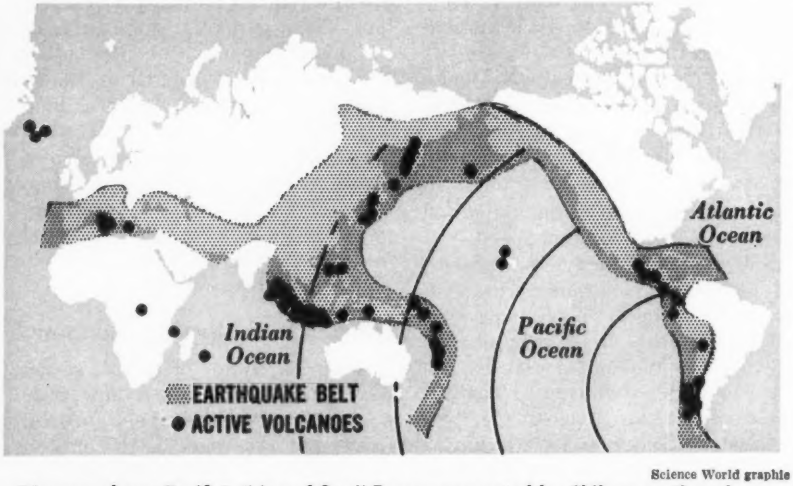
World Warning Network

There is almost no part of the great Pacific region that is safe from tsunamis. For this reason, the tsunami warning system has been established. The system's nerve center is in Honolulu. Other stations of the U.S. Coast and Geodetic Survey warning system are located on the Pacific island of Guam; in Tucson, Arizona; and at Sitka and Fairbanks in Alaska. Seismic data are also furnished by a number of American, Japanese, South American, and Philippine stations.

When earthquake shock waves trigger the alarms in this network, as they did May 23, observers watch for the early signs of tsunamis. Then, armed with knowledge of how fast these waves travel over different parts of the ocean, they issue alerts.

Local officials take appropriate action. Thus, even today's limited scientific knowledge of "tidal waves" has made possible a life-saving warning service.

This month the Soviet Union is joining with the U. S. and Japan in widening the service to include all of the Pacific.



Science World graphic

Diagram shows Pacific's "ring of fire." Energy generated by Chilean earthquake was carried across Pacific to Hawaii, Philippines, Japan. Note progress of wave front.

By SIMON DRESNER

The search for the ultimate indivisible particle of matter has led to the heart of the atom

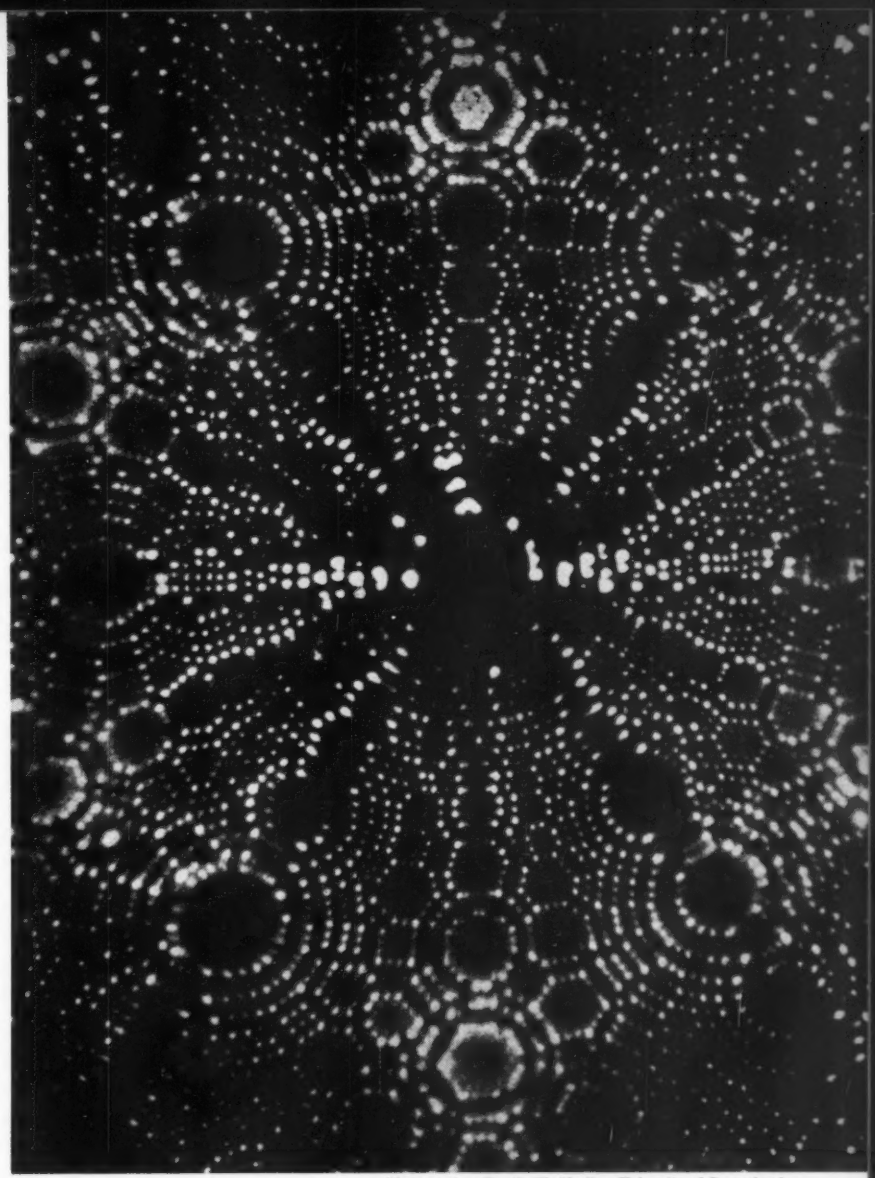


Photo courtesy Dr. E. W. Mueller, University of Pennsylvania

Each dot of light in this photograph is the actual image of a single atom of tungsten. The photo as a whole is the image of a single crystal of tungsten located at the tip of a very fine tungsten needle. The picture was taken with a field emission "microscope." This microscope uses very high voltages to tear ions from tip of needle and shoot them toward a fluorescent screen, with resulting image.

THE SEARCH FOR THE BUILDING BLOCKS OF MATTER

THE town of Abdera, in Greece, was a sleepy and uninteresting place around 430 B.C. The citizens of Abdera, however, had one interesting diversion—talking about the latest ravings of their fellow townsman, an eccentric named Democritus. They called him the "laughing philosopher" because he had squandered his fortune and laughed at the serious merchants of the town. Democritus did not think that the activities of men were worth worrying about. Instead, he preferred to think about the universe.

After many years of thought, Democritus came to believe in the existence of atoms. To him, an atom was an extremely small, invisible particle that moved about through space. His atoms were indestructible and could not be divided. Everything in the universe was constructed of these atoms, which varied in size and shape.

This idea was too advanced for his fellow citizens. They believed the universe was made up of earth, water, rock, and the other things they saw around them. But Democritus felt that the senses—such as taste and touch—did not give a true picture of the universe. He taught that there is nothing in the universe except atoms and empty space in which atoms move.

Democritus had never seen an atom, and had no experimental evidence that atoms existed. However, Democritus, and other Greek philosophers, gave us the idea of the atom as the building block of matter. In fact, the term atom is derived from two Greek roots, *a* (not), and *temnein* (to cut)—something that can-

not be cut, something which is indivisible.

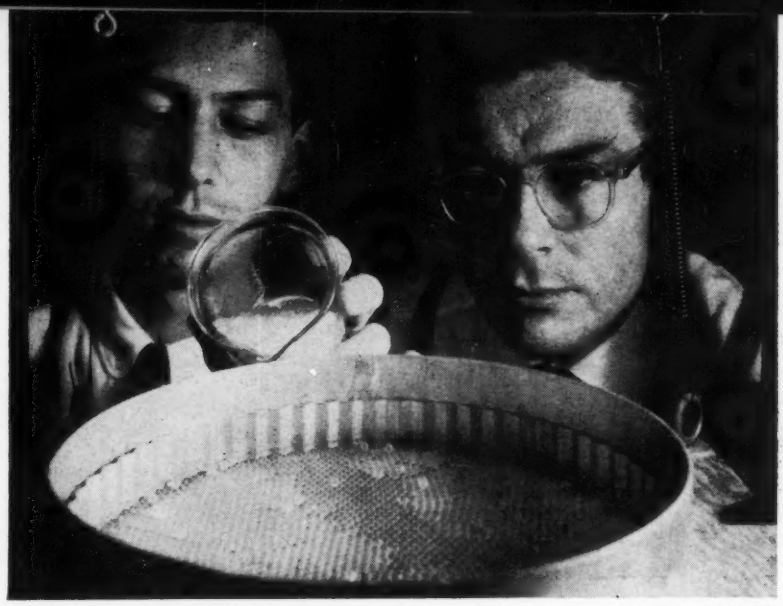
The Greeks liked to ponder problems, but they did not care much for practical scientific experimentation. More than 2,000 years went by before an English schoolteacher, John Dalton, showed that the ideas of the ancient Greeks might have some relation to the real world. Dalton believed that atoms really existed. He even tried to weigh them. Dalton realized that atoms were much too small to be weighed on a scale. Therefore, he decided to compare the mass of the atom to a standard. He chose the atom of hydrogen as his standard, since it was the lightest substance.

However, Dalton was thinking of molecules, rather than atoms as we conceive of them today. The word *molecule* is derived from the diminutive of the Latin *moles,* meaning mass. Therefore, molecule means merely a small mass.

Dalton's Guess

Today we define a molecule as a particle of any substance—whether element or compound—as it normally exists. Atoms of one element may combine with other identical atoms to form molecules. Thus an atom of hydrogen can combine with another atom of hydrogen to form a hydrogen molecule. An atom may also combine with one or more atoms of different elements to form molecules of chemical compounds. For example, a molecule of water is represented by H_2O, a symbol describing the molecule as made up of two atoms of hydrogen and one of oxygen. In this case both elements became unrecognizable when they joined to form the compound. This happens frequently when compounds are formed.

Dalton talked of chemical elements as fundamental materials of which all matter is made. This idea —of basic building materials making up all things we are familiar with— was also in the minds of the ancient Greeks. In the fifth century B.C., the philosopher Empedocles thought that all matter was composed of four "elements"—earth, air, fire, and water. The philosopher Aristotle supported this theory. It went unchallenged for almost 2,000 years. In 1774 the French chemist Lavoisier proved that air was not a simple substance, but a mixture of at least two different gases, which we now identify as oxygen and nitrogen.



General Electric photo

Marbles mimic behavior of atoms when thrown upon vibrating tray. Plate is suspended by springs, jiggled at random by motor. Beads jump from hole to hole, like atoms.

Seven years later two English scientists, Joseph Priestley and Henry Cavendish, showed that water was also composed of two elements—hydrogen and oxygen.

These two discoveries compelled scientists to abandon the four-element theory forever. In its place, Lavoisier established the modern concept of a chemical element. Lavoisier substituted for the four elements of the Greek philosophers more than thirty-three elementary substances. Twenty of these substances are still regarded as elements.

With these theories of Aristotle discredited, progress was rapid. Thirty years after Lavoisier, a Swedish chemist, J. J. Berzelius, increased the number of known chemical elements to 50.

As each additional element was discovered, chemists determined its atomic weight. By 1869, atomic weights had been correctly established for many of the elements then known. At that time a great Russian chemist, D. I. Mendeleyev, arranged the elements in order of their atomic weights, beginning with the lightest, hydrogen.

He made a startling observation. All the elements could be arranged into groups with similar chemical and physical properties, making up what is known as the periodic table.

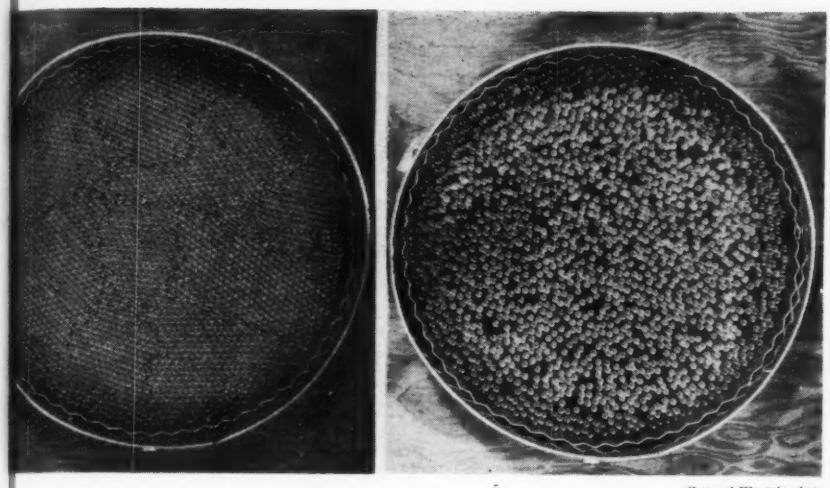
On the basis of his table, Mendeleyev made a bold proclamation: If any element did not fit into his periodic table, its atomic weight was incorrect. Also, Mendeleyev predicted that the vacancies which existed in his periodic groups of elements would be filled by elements as yet undiscovered. Mendeleyev even predicted what the properties of these elements would be.

Mendeleyev's periodic table and his predictions took on real significance when, years later, three new elements were discovered—gallium in 1875, scandium in 1879, and germanium in 1886. The properties of these elements were precisely as Mendeleyev had predicted.

The Search Continues

Mendeleyev's great formulation of the periodic table of the elements settled the question of finding the fundamental materials of which our world is made. But it opened the way for another question: Are the fundamental materials really fundamental, or are they made up of even more basic materials? Scientists began to theorize that each element is made up of invisible particles which give the element its characteristics—in other words, atoms.

Furthermore, the periodic table suggested that all the elements were related in a progressive and orderly manner. If each element was made up of atoms, then it had to follow that the atoms of the different elements were also somehow related.



General Electric photo

Loosely packed marbles *(right)* jump around like atoms in liquid. More closely packed marbles *(left)* simulate structure of solid, showing several boundaries, as in crystal.

Not until more than 50 years later was this relationship, based on the structure of the atom, discovered.

Within this time, new instruments were invented and new methods were devised for studying atoms. What a picture emerged! It was found that all elements are made from the same fundamental particles —protons, neutrons, and electrons. What makes one element different from another is nothing more than the specific number of protons, neutrons, and electrons involved. And atoms were found to be incredibly small.

The Mighty Mite

Roughly, ten million atoms would stretch across the head of a pin. Also, most of an atom is empty space. If an atom were enlarged until it were as large as a football stadium, its electrons would be like flies flying around the outside of the stadium. The nucleus would be about the size of a golf ball in the center. It would be thousands of times heavier than all the flies put together. Yet scientists today can go so far as to determine the mass and weight of this mite—the atom—with an accuracy of one part in a million!

Today, measurement of the size of atoms of the lighter elements is based largely on studies of the motion of atoms. The diameters of atoms can be derived from the way in which gases move and flow. In this way, the diameter of the hydrogen atom, the smallest of all, is found to be 1.35×10^{-8} cm.

The radii of atoms are usually expressed in Angstrom units, named after a Swedish physicist, A. J. Angstrom. One Angstrom unit, represented by the symbol A, is equal to 10^{-8} centimeters.

The smallest speck of matter which can be seen in a good light microscope would have to contain at least a billion (10^9) atoms. Individual atoms are so small that they cannot be detected even by the most powerful electron microscopes, which magnify about 100,000 times. However, some of the very large molecules occurring in nature, such as protein molecules, have now been observed with the electron microscope. But keep in mind that each of these complex molecules consists of thousands of atoms.

With all this evidence in hand, scientists were satisfied that all matter was really made up of tiny molecules and atoms. From studies of gases and liquids, nineteenth-century scientists were convinced that these tiny particles were in constant motion.

This phenomenon had first been observed in 1828 by an English botanist, Robert Brown. He had noticed that when microscopic pollen grains were suspended in water, they showed continuous haphazard motion in all directions. This phenomenon, which can be observed with small suspended particles of many kinds, is called Brownian movement, in honor of its discoverer. The motion of the suspended particles is attributed to the "kicks" given them by the moving molecules of water.

But how could this motion of billions of particles be responsible for giving solids, liquids, and gases the properties we are familiar with—such as temperature, pressure, density, etc.?

The first attempts to make this connection between atoms and matter in bulk were based on the laws of motion set forth by Sir Isaac Newton in the seventeenth century. Newton's laws apply to any attraction or repulsion between bodies in space (whether tiny atoms or large planets).

But it was not until the nineteenth century that Ludwig Boltzmann, James Clerk Maxwell, and other scientists tried to apply Newton's laws to the motion of molecules. Their predecessors had worked on the problem of computing the orderly motion of a few planets under the gravitational attraction of the sun. These scientists, however, were concerned with millions of particles colliding with one another, at high speeds, in all directions.

Computer to the Rescue

Furthermore, the motion of each particle is affected by the position and motion of all the particles directly around it. Assuming that Newton's laws of motion applied, calculating the motion of any individual particle would be a hopelessly complicated task.

Fortunately, statistics came to the rescue. In describing gases, physicists began talking about the average molecule, rather than the individual molecule—just as sociologists today speak of "typical" and "average" people in studying the behavior of millions of persons.

Today we know that between each pair of molecules in a sample of matter is a force which varies with the distance between them. If we know the degree to which the force varies with distance, we can compute forces exerted on a typical molecule by its neighbors. In such ways, we can compute the pressure of gases and other molecular phenomena.

Also, a high-speed computer can

carry out a large number of rapid calculations and come up with conclusions on the motion of these "fictitious" particles, whether molecules or atoms. These conclusions then hold for real particles, such as the molecules in a gas or liquid. The computer's mathematical method uses random numbers, similar to those which would turn up on a roulette wheel. This method is called the Monte Carlo method, after the Casino in Monte Carlo.

The computer can follow the detailed motions of about 500 particles, although more advanced computers planned for the future will be able to follow the motions of 10,000 particles. This number is small compared to the billions of particles in a tiny sample of gas or other matter. However, the study of even this small number of particles has provided scientists with significant results.

The computer begins its calculations by assigning to each of its 500 particles—which we might think of as little hard spheres, like marbles—a position and a velocity (direction and speed). The machine assigns these values at random, as it might pick numbers from a roulette wheel.

After this, the element of chance is removed. The machine calculates the path of every particle until two of them come close enough to exert a force upon each other. Using Newton's laws of motion, the computer then determines the effects of the force on the two particles, and calculates their new velocities after the collision. The computer continues to compute the paths of all the particles until a second pair interacts, and so on.

Theories for Tomorrow

At any time during these calculations, the computer can be stopped momentarily and the immediate position of all the marbles recorded. This is equivalent to taking a "snapshot" of the marbles in motion. The "snapshot" can then be studied and the distance between each particle and the others measured. If a number of "snapshots" are taken, the average distance between our marble-molecules can easily be calculated.

We know that the distance between molecules determines such properties as pressure, viscosity, and state (solid, liquid, or gas). Thus the computer can actually predict these properties for existing and nonexisting substances made up of its fictitious marble-molecules.

In this way, computing machines will probably help to develop new theories of the molecular and atomic structure of matter. The computer has the advantage of being able to simulate states of matter not easily achieved in the laboratory, such as ultra-high or ultra-low temperatures and pressures.

Tireless computers can carry out tedious mathematical calculations which would otherwise be impossible to perform. The results of these calculations may enable scientists to discover new physical laws describing the behavior of molecules and atoms.

Computers may eventually be a source of scientific data as important as the laboratory experiment. The relation between molecules and matter may become clearer, bridging the gap between the matter perceived by our senses and the invisible particles of which it is made.

Next issue: The forces that hold matter together.

COMPUTER ROULETTE—THE MONTE CARLO METHOD

The Monte Carlo method is actually a game of chance played thousands of times by a high-speed computer. The game can be designed to represent the effects which thousands of particles may have on each other. The following game represents atomic particles hitting and penetrating a block of material (in this case a shield against radioactivity).

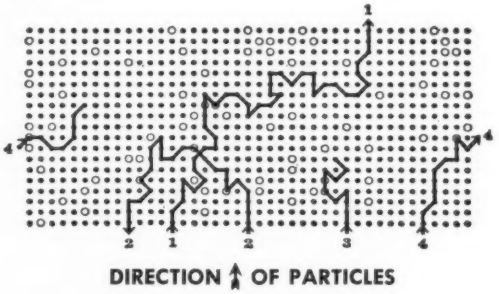
The black dots and white circles in the diagram represent two kinds of atoms within the shield material. As each particle enters the shield, its move from atom to atom is determined by chance by the computer.

The computer picks numbers from a built-in electronic "roulette wheel." The numbers selected determine the moves of each particle according to the rules of the game. According to the rules of the game, when an individual particle hits an individual atom, the particle can be absorbed, or it can be deflected in any one of four directions.

The problem shown here was worked out on an I.B.M. 704 computer. In seven minutes the computer represented 7,600 particles making a total of 91,476 moves. The result: 39.2 per cent of the particles were absorbed; 45.4 per cent were reflected in the direction from which they came; and 15.4 per cent passed through the shield to the opposite side. If the rules of the game are correct, the computer's result should be the same as if it had followed the movements of real particles in a real shield against radioactivity.

RULES OF THE GAME

Particle's next move	if it starts on black . . . and the number is:	if it starts on white and the number is:
Absorbed	1	1, 2, or 3
Three forward	2 or 3	——
Two forward	4, 5, or 6	4
One forward	7, 8, 9, or 10	5, 6, or 7
One right, one forward	11, 12, 13,14, or 15	8, 9, 10, or 11
One left, one forward	16, 17, 18,19, or 20	12, 13, 14, or 15
One right	21, 22, or 23	16, 17, 18, 19
One left	24, 25, or 26	20, 21, 22, or 23
One right, one backward	27, 28, 29, or 30	24, 25, 26, 27, or 28
One left, one backward	31, 32, 33, or 34	29, 30, 31, 32, or 33
One backward	35 or 36	34 or 35
Two backward	——	36



Adapted from The New World of Math, by G. A. W. Boehm (Dial)

By THEODORE BENJAMIN

MEETING THE TEST

Just back from vacation? Get the gears in mesh again by trying your hand at this quiz on modern science. Of the four choices given, select the letter of the most appropriate answer. Answers will be found at the bottom of this page, but don't peek!

1. Of the following, the element which is man-made and does not occur in nature is:
   (a) dysprosium (c) niobium
   (b) europium (d) promethium

2. The most abundant elements, in as much of the universe as our telescopes and spectroscopes can probe, are:
   (a) silicon and oxygen
   (b) hydrogen and helium
   (c) iron and nickel
   (d) nitrogen and oxygen

3. Atoms of semiconducting materials are characterized by which of the following types of bonding:
   (a) metallic (c) covalent
   (b) ionic (d) Van der Waals

4. Hysteresis is a term most likely to be found in a textbook on
   (a) biochemistry (c) physics
   (b) medicine (d) psychology

5. Ferrites are:
   (a) small iron meteorites
   (b) magnetic non-conductors
   (c) a variety of steel
   (d) small animals that kill snakes

6. The range between the deepest known ocean depth and the greatest height of the highest mountain is
   (a) 6 miles (c) 12 miles
   (b) 8 miles (d) 18 miles

7. Which of the following chemicals is a plant growth stimulant?
   (a) adipic acid (c) gibberellic acid
   (b) ethanol (d) glutamic acid

8. Estivation is most closely related to
   (a) esterification (c) levitation
   (b) saponification (d) hibernation

9. The first symptom of radiation damage in whole-body radiation of human beings is:
   (a) the falling out of hair
   (b) the lowering of the white blood cell count
   (c) nausea
   (d) great thirst

10. Cerenkov radiation is produced when
   (a) a particle moves faster than 186,000 mi/sec
   (b) a particle moves through a medium faster than the velocity of light in that medium
   (c) a proton and electron collide
   (d) a light ray strikes fluorescent material

11. Radioactive carbon (C-14) with a half-life of 5,000 years is
   (a) not normally present in living tissue
   (b) present in all living things
   (c) not present in fossil remains over 5,000 years old
   (d) present only in plant tissue

12. Allergies are most closely associated with
   (a) the production of toxins by bacteria
   (b) modification of the antigen-antibody reaction
   (c) transmission of characteristics by heredity
   (d) disturbances between interrelated endocrine glands

13. The best modern microscope cannot resolve objects whose distance apart, in inches, is less than
   (a) 2×10^{-10} (c) 2×10^{-6}
   (b) 2×10^{-8} (d) 2×10^{-4}

14. Most recently, it was discovered that attenuated live virus vaccine is effective in the prevention of
   (a) measles (c) polio
   (b) smallpox (d) tetanus

15. Project Ozma will
   (a) study ways of controlling thermonuclear energy
   (b) attempt to receive radio wave communication from intelligent beings beyond the solar system
   (c) drill a hole in the ocean bottom
   (d) study the movement of the Earth's geographic poles

16. Man upsets the balance of natural processes by adding billions of tons of carbon dioxide to the atmosphere each year. This accumulation of carbon dioxide may influence the Earth's climate by
   (a) preventing the ultraviolet light in sunlight from reaching the Earth
   (b) preventing the escape of infrared radiation from the Earth
   (c) causing green plants to release more oxygen
   (d) darkening the sky

17. Studies in the field of magnetohydrodynamics are leading to an improved method of
   (a) de-salting water
   (b) dam construction
   (c) power production
   (d) navigation

18. The fermi is a unit of
   (c) time (a) length
   (d) velocity (b) mass

Answers

1. (d); 2. (b); 3. (c); 4. (c); 5. (b); 6. (c); 7. (c); 8. (d); 9. (b); 10. (b); 11. (b); 12. (b); 13. (c); 14. (a); 15. (b); 16. (b); 17. (c); 18. (a).

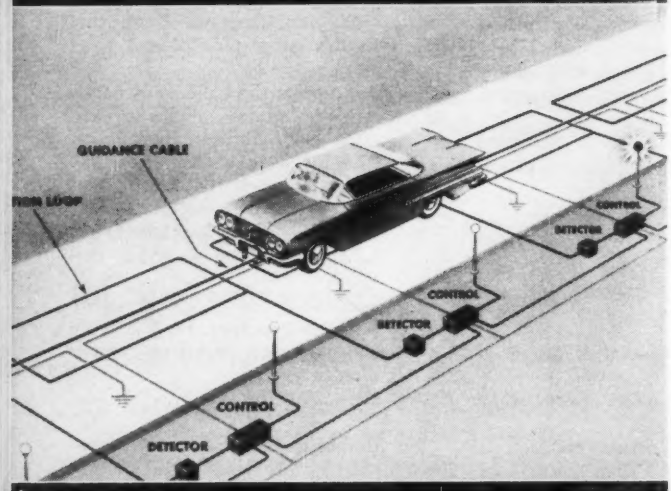
SCORE BOX

Right_____

Wrong_____

Score_____

Science in the news



RCA photo

1. Electronic highway removes possibility of human error in driving. Coils on car's bumper (*top*) pick up signals from detectors along road (*middle*). No driver is needed (*bottom*).

What's Behind the Photos

1. Highway of Tomorrow?

Cars without drivers are speeding along a 300-foot stretch of electronic highway built by RCA to test an automatic control system for automobiles. Loops of wire, about one car length each, are buried close to the surface of the road to detect the presence of a car. As a car passes over a loop, the loop transmits a signal which can operate traffic lights, set speed limits, and flash warning signals. Signals from the loop also control a car's brakes and accelerator, automatically keeping it at safe driving distance from other cars.

The automatic steering system is guided by a single cable buried in the pavement along the center of the traffic lane. A signal current in this cable is picked up by two wire coils mounted on the car bumper.

2. Future Scientists Make Headlines

Joseph Tate, who was graduated from Normandy (Mo.) High School last spring, has built a one-million-electron-volt cyclotron. This month Joseph and his atom smasher are going to the University of Kansas—Joseph as a freshman and his cyclotron as a permanent resident.

Robert Owendoff, a 15-year-old high school student at Falls Church, Va., has developed new types of sundials for telling time and direction. The U. S. Defense Department is interested in two of Robert's inventions—a pocket navigator and a direction finder for lost soldiers.

3. Ruby Light for Space Signals

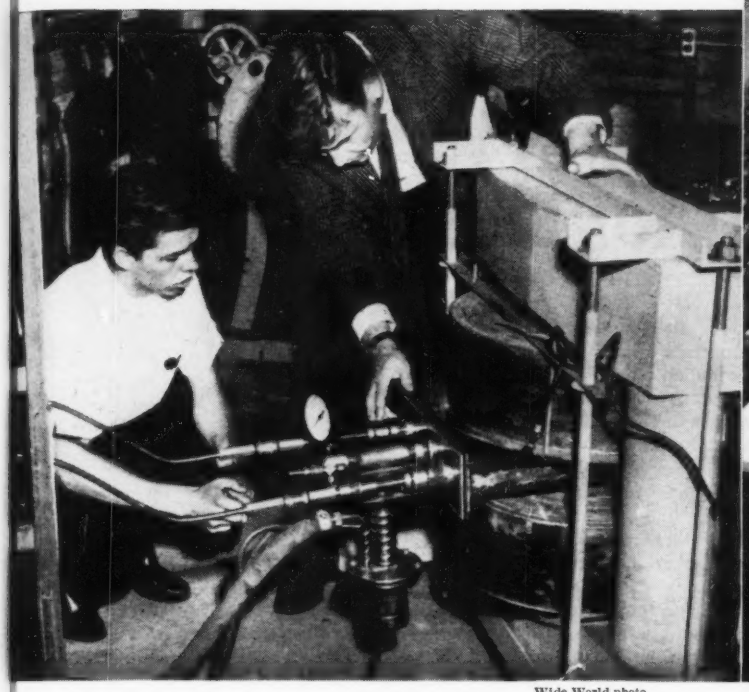
A new type of light may one day be used to flash signals to the moon. The powerful light is generated by a synthetic ruby crystal in a device called a LASER (short for *Light Amplification by Stimulated Emission of Radiation*). The ruby LASER is similar to a radio transmitter, except that it broadcasts light waves instead of radio waves.

All the light rays from the LASER are perfectly parallel, shining in the same direction, like the beam of a spotlight. If a LASER light beam were sent from Los Angeles to San Francisco, it would spread only 100 feet. An ordinary searchlight beam would spread 50 miles.

4. World's Largest Atom Smasher

After six years and $31,000,000, the largest atom smasher in the world is whirling atomic particles at Brookhaven National Laboratories, N. Y. The atom smasher can accelerate atomic particles to energies of 30 billion electron volts, at velocities almost as high as 186,000 miles per second—99.999 per cent as fast as the speed of light.

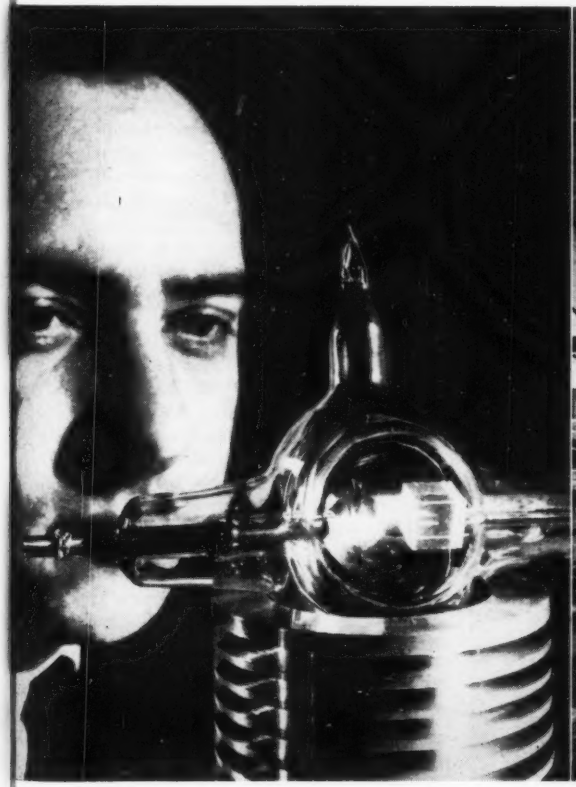
The huge doughnut-shaped machine is called an Alternating Gradient Synchrotron, after the design of the 240 magnets which keep the particles on their circular track and prevent them from flying off in a straight line. The particle "bullets" used in the machine are atoms of ordinary hydrogen, each stripped of its electron by an electric spark, leaving the proton nucleus. Pulses of radio waves accelerate the protons 300,000 times around the half-mile magnetic track until they crash into the target atoms, smashing the nuclei.



Wide World photo

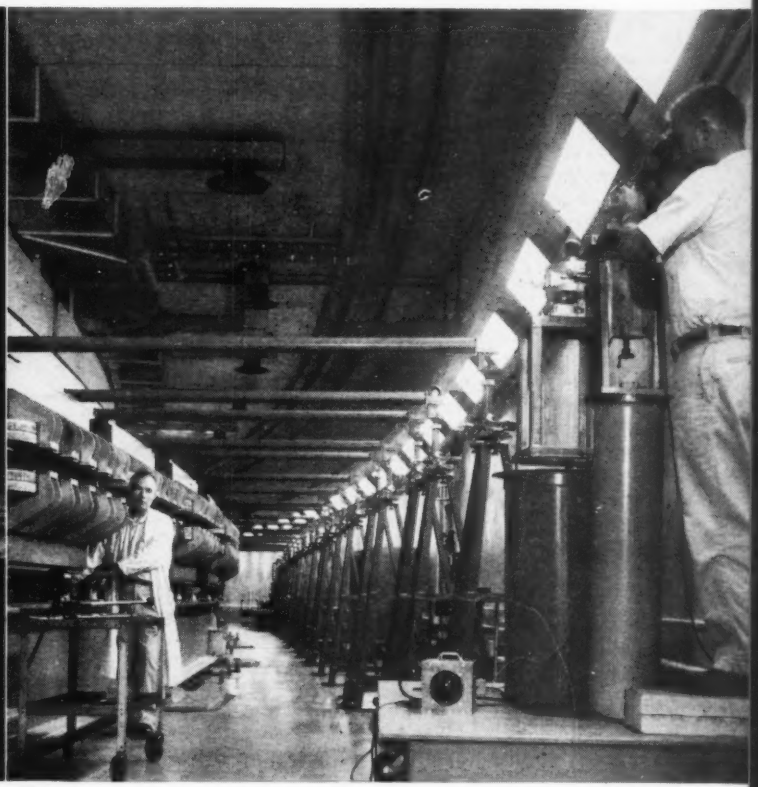
Wide World photo

2. Students in science news are Joseph Tate (*above, left*)—shown demonstrating his one million-electron-volt cyclotron—and Robert Owendoff (*above*), high school sundial expert who has interested U. S. Defense Department in two inventions.



UPI photo

3. Tiny cube inside glass tube is ruby LASER, first device to amplify light. Tightly packed atoms of gem intensify light.

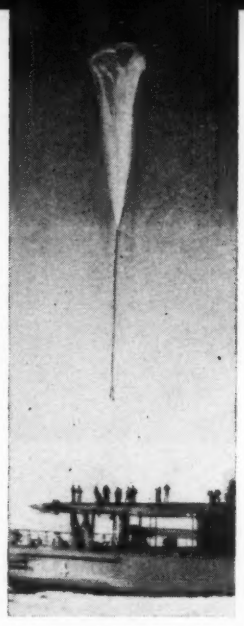


Brookhaven National Laboratory

4. Surveyors line up poles of magnets in world's largest atom smasher. Particles reach speed nearly as fast as light.

today's scientists

DR. HERBERT FRIEDMAN . . . ROCKET ASTRONOMER



IN an unusual two-for-one shot, the United States placed two satellites into orbit with one rocket last June. One of the "piggyback" satellites was a 223-pound navigational satellite.

The second of the two satellites—only 43 pounds but crammed with astronomical instruments—was designed to measure the sun's radiation from above the absorbing blanket of the Earth's atmosphere. This achievement marked the first step toward an astronomical observatory in outer space.

For Dr. Herbert Friedman, 43, who developed the instruments packed in the satellite, this was a milestone in his career as an astrophysicist. (Astrophysics is the science of applying the theories and techniques of physics toward the study of the universe.)

Switched from Art to Physics

Scientific milestones are not achieved overnight. The successful satellite is the result of many years of patient work by Dr. Friedman. In a sense, he is a convert to science, having originally enrolled at Brooklyn College as an art major. The son of an art dealer, young Herbert Friedman intended to follow his father's career. During his junior year, however, a physics professor persuaded him to switch his major from art to physics.

Dr. Friedman went from Brooklyn College to The Johns Hopkins University in Baltimore, Maryland, where he received his Ph.D. degree in 1940. He remained at Johns Hopkins as a physics instructor for a year before joining the staff of the Naval Research Laboratory, where he is now superintendent of the Atmosphere and Astrophysics Division.

The scientist who studies the universe can study the sun, moon, and stars only indirectly. One of the phenomena he can measure with ground-based instruments is the radiation emitted or reflected by these bodies. Vast quantities of radiation are emitted in the universe, but on Earth we see only a narrow band of these rays. Much of the rest of the energy spectrum is absorbed by the atmosphere. It does not reach the Earth.

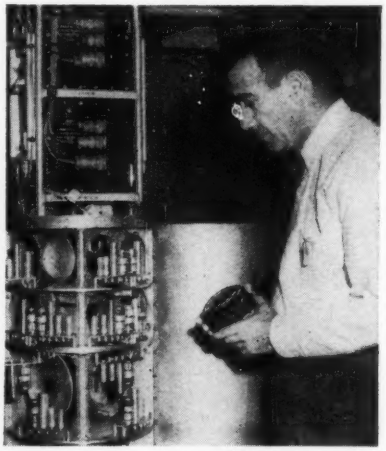
This absorbed radiation could give us an enormous amount of information about the processes of the universe. To get this information, scientists must be able to probe *above* the atmosphere, where these rays or their effects can be observed and measured.

Today instruments inside Earth satellites can take these measurements. A few years ago, the only way to get above the atmosphere, even briefly, was by means of rockets. At best, rockets could give fragmentary information.

The sun, our closest star, was the first body to be studied by rocket astronomy. Astronomers had long been interested in the various forms of solar activity—sunspots, plages, prominences, and, most spectacular of all, flares.

(The solar flare is a very bright outburst on the face of the sun, generally observed in the vicinity of large, irregular sunspots. It may last from only a few minutes to an hour or even longer. The occurrence of solar flares is irregular and unpredictable.)

Every time a large flare occurred, it had been accompanied by a sudden fading of radio signals all over the world. Scientists believed this phenomenon, known as "radio fadeout," involved a change in the ionosphere. This is the layer of the atmosphere from which radio waves are reflected. In the presence of a flare, however, the radio waves apparently were absorbed by the ionosphere rather than reflected back to Earth. Many scientists assumed that a flare emitted large amounts of ultraviolet radiation, and this radiation caused changes in the ionosphere.



Official U. S. Navy photo

Dr. Herbert Friedman, "father" of new science of rocket astronomy, installs tiny ultraviolet telescopes in rocket.

Dr. Friedman and his associates at the Naval Research Laboratory had another idea. It was their belief that solar flares emitted X rays and not ultraviolet radiation.

"The only way to settle this question," Dr. Friedman explained, "was to put both ultraviolet and X-ray detectors into a rocket and get it into the ionosphere at the time of a solar flare."

On the Flare Patrol

This was not as simple as it seemed. "A flare doesn't give you any warning of when it's going to start," Dr. Friedman pointed out. "Flares don't occur very frequently. They flash to their peak brilliance in a matter of perhaps five minutes. In that short interval you have to decide to shoot, and gamble that the flare will not fizzle, but will turn out to be a spectacular one."

In 1956 Dr. Friedman attempted his first shoot. He equipped a rocket with delicate instruments, one sensitive only to ultraviolet light and the other sensitive only to X rays. When radiation was detected by either of these tubes, this information was telemetered back to Earth by a small radio transmitter.

From the deck of a ship, he and his associates launched a rockoon—a combination of rocket and balloon. The rockoon was launched to a height of 80,000 feet early in the morning. It floated at that level as the day went on. When a flare was detected, the rocket

(Continued on page 30)

tomorrow's scientists

PROJECT: The Life History of the Butterfly, Euptychia mitchellii

STUDENTS: **STEPHEN HUBBELL and THOMAS PLISKE**, Grade 12

Winners, Student Achievement Award, Future Scientists of America

School: Ann Arbor High School, Ann Arbor, Mich. TEACHER: **JOHN C. ROSEMERGY**

[When Stephen Hubbell and Thomas Pliske began their study of the little butterfly, Mitchell's satyr, they were certain their project was original. But, when their work was completed, they found that another amateur had done essentially the same work 28 years earlier.

Was the effort of Stephen and Thomas wasted? No—it was found that the two studies not only confirmed each other; each offered something that the other had overlooked. The boys and the older man then pooled their knowledge and prepared a joint research paper that will soon be published in a scientific journal.

The story of the project illustrates two important principles of research: To keep the record straight and science moving forward, it is important to publish research. And an important first step in any project is to search the scientific literature to benefit from the findings of earlier workers.

This project and the one that follows show that clear thinking—not expensive equipment—makes a project worthwhile.]

STEVE AND TOM'S PROJECT

Euptychia mitchellii French, or Mitchell's satyr, is an inconspicuous brownish butterfly, known to live in only a few secluded places in southern Michigan and nearby Indiana. Its habitat is a variety of bog characterized by tamarack and poison sumac. Because of its limited and rather inhospitable environment, this species is one of the few butterflies of the United States whose life history and habits have not been described in a published report.

The adult butterfly has a wing spread of 1.2 inches to 1.5 inches. The upper wing surfaces are a rich mahogany brown in the male and dark buff in the female. The background coloration of the lower wing surfaces is dark buffy brown, and each lower wing surface has a submarginal row of ocelli (eye spots), three or four on the fore wing and five or six on the hind wing. Also, on the under surface, both fore and hind wings have two reddish brown bands at the margins and faint lines in the central part.

The little wood satyr, whose range overlaps that of Mitchell's satyr, is considerably larger. Two ocelli on both the upper and lower surfaces of all wings also distinguish it from Mitchell's satyr.

Sharon Hollow bog, the site of our field studies, is bordered on the south by a mature, apparently virgin, beech-maple forest, equaled in grandeur by few others in southern Michigan. To the west there lies a sloping field, beyond which is a shallow lake. A small creek winds eastward from this lake through the bog. The creek divides the bog into a southern section containing all of the tamarack and most of the poison sumac, and a northern section—a wet meadow where sedges, grasses and shrubby cinquefoil dominate.

The date of our first visit to the bog, July 5, 1958, was chosen to be close to June 28, the earliest date adults of *Euptychia mitchellii* are recorded in Michigan. The day began with overcast skies. By the time the bog was reached —11:30 a.m.—it was raining and very few butterflies of any kind were seen.

During short sunny intervals in the afternoon, *Euptychia mitchellii* could be seen flying about.

Euptychia mitchellii has a slow, weak, bobbing flight. It never flies more than a foot above the grasses and sedges. It appears and disappears in and out of the grasses, giving the effect of dancing and bobbing. Its characteristic flight distinguished it from the common little wood satyr which often strayed into the bog. The little wood satyr flies more strongly, often in a zigzag manner high about the foliage of a tree. Sometimes, the little wood satyr sits, sunning itself upon the leaves of a tree. Then it drops suddenly to the level of the grass tops and remains there for some time.

We followed four males of *mitchellii*. During the intermittent showers they rested in some sheltered place, assuming a vertical position with the head up or down.

A second field trip was made on July 8, a clear sunny day. The number of *mitchellii* had increased tremendously.

Counts made in representative areas of the bog led to an estimate of 500 individuals in the colony.

A Single Female

In the boggy meadows individuals were easy to follow. But, inevitably they seemed to fly directly toward an impossibly dense stand of poison sumac or wall of tamarack trees. It was seldom possible to follow a single butterfly for more than a quarter of an hour.

That day 13 males of *Euptychia mitchellii* were captured and released. A single female was found late in the afternoon. On the basis of these observations it appeared that the ratio of males to females in this locality might have been at least ten to one.

All our attention was focussed on the female. Her abdomen was swollen with a heavy burden of eggs, and she flew in short "jumps" of less than two feet, from sedge to sedge. She alighted more often than not on a sedge, *Carex stricta*. We hoped that this was the food plant of the larva, but the female laid no eggs on the sedge.

As evening approached she stopped flying. She was preparing to rest for the night. Because this was the only

female found, it seemed best to collect her alive. We could observe oviposition (egg laying) in the laboratory. In the field we might miss observing this process. She was placed in a container with moist paper towelling in the bottom along with samples of grasses and sedges to be tried as food plants.

On July 11, our third visit to the bog, the skies were partly cloudy. Intermittent cloudiness brought to particular attention the flight behavior of *Euptychia mitchellii*. As drifting clouds hid the sun, individuals in flight landed almost immediately. When the sun reappeared they began to fly again. A striking example of this behavior was observed while watching several of the butterflies in the wet meadow north of the creek. Within a few moments after the sun had been eclipsed by a small cloud, every individual had dropped out of sight into the grass. Five minutes later the cloud had passed and they were all on the wing again. Some individuals, however, did fly during long cloudy periods.

Rearing Notes

July 9—Set large glass jar containing female, moist soil and live *Carex stricta* in east window exposed to morning sun. Fifteen lime-green eggs, 1 mm. in diameter, laid singly or in groups between 12:15 and 3 p.m.

July 10-16 — Ninety two eggs laid. Each egg, attached to a piece of sedge, was put into a dated vial, placed so that the eggs received the early morning sunlight. Two drops of water were put into each vial daily.

July 17—Female died after laying 107 eggs. Minute larvae were visible through the transparent shells of several of the eggs laid on July 8.

July 19—Two eggs hatched at 5:00 p.m. Each larva first made a rip in the egg shell. Then it ate a hole large enough to pass through. Average hatching time was five minutes. Larvae have large violet-brown heads and slender lime-green bodies 2.5 to 3.0 mm. in length. At 5:00 pm. larvae ate a little fresh *Carex stricta* leaf.

July 20—Eleven eggs hatched. These caterpillars sampled *Carex stricta* but did not eat voraciously. Six other kinds of sedges and grasses were tried. One sedge, *Carex cephophora*, proved acceptable, and the larvae began to eat it immediately. It was concluded that *Euptychia mitchellii* probably has more than one natural food plant.

July 21-24—Eggs continue to hatch. A total of 47 larvae emerged—44 per cent of all eggs laid. Larvae ate continuously day and night.

August 1—First moult occurred in three individuals. Length 5.5 to 6.0 mm. Shed skins were not found, and it was assumed they were eaten. Instar II (larval stage between moults) was entirely lime-green.

August 6—Forty individuals had gone through first moult.

August 13—Four of the second instar larvae moulted. Length at emergence 7.5 to 11.0 mm. Darkening of head seems to indicate forthcoming moult.

August 18—Thirty three of the instar II larvae had moulted.

August 26—No further moults. One third of the instar III larvae were placed out-of-doors to simulate natural conditions, in the event that *mitchellii* over-winters as a larva in this instar.

September 3—Twenty six of the instar IV larvae emerged. Length 8.5 to 16.0 mm. Rate of eating increased somewhat, but did not equal that of instar II larvae. The larvae out-of-doors showed a reduction in eating. Cooler temperature may have caused this.

September 20—Three of the instar V larvae emerged. Length 11.0 to 22.0 mm.

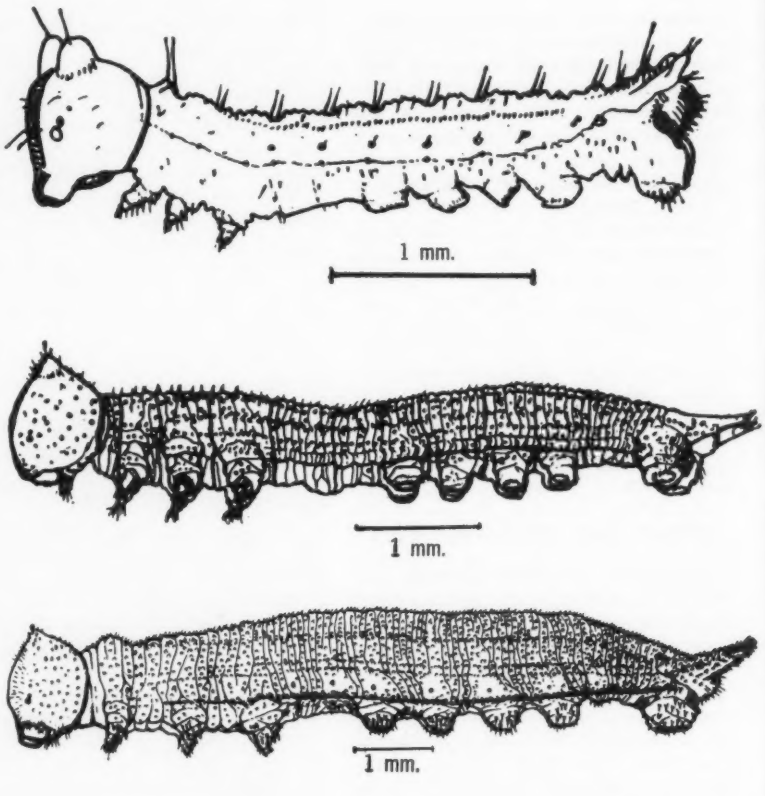
October 14—Two of the instar V larvae attached themselves head down to side of vial by means of a patch of silk, with head curled inward toward glass. Chrysalid could be seen inside larva. Before this occurred, the larvae had been eating vigorously. The larvae out-of-doors had completely stopped eating; they became stiff and dropped to the bottom of the vials.

October 15—First pupa. Length—10.5 mm., maximum width—4 mm. Color about same as that of larva, but with bluish-white mottlings on surface.

October 27-November 13—All healthy larvae (10) pupated. Length of pupae 11 mm to 14 mm. Five pupae produced adults. Duration of pupal period: 17 days. The five adults of *Euptychia mitchellii* were mounted with data, and their chrysalid cases (pupal skins) were preserved.

Five Stages or Six?

Would cold prevent pupation in a larva which had suspended itself in preparation for it? Two such larvae



Stephen Hubbell

The skin of an insect also serves as its skeleton. In order to grow, an insect must shed its skin each time the skin becomes tight. As Mitchell's satyr "grows up" from caterpillar to butterfly, it sheds its skin at least five times. Each stage is called an instar. Drawings above were made with camera lucida (an instrument that casts images on drawing paper). They show first three instars of larvae raised by Stephen and Tom.

were placed out-of-doors. No pupation took place. A maturing pupa was also placed out-of-doors. No change.

March 10—The larvae placed out-of-doors in August are still in instar IV. Before they can emerge as adults in July, they will have to finish their present instar, pass through instar V, and go through the pupal period.

However, if our findings about the lengths of time spent in the various instars are correct, adult butterflies would emerge in the middle of June. But field observations do not report adults before June 28. Perhaps a sixth instar exists in the normal life history. The assumption is reasonable. Other species of this genus are known to pass through six larval instars. Furthermore, one entomologist, who has done some work on *Euptychia mitchellii*, believes it to have six larval instars. Indeed, the merging of two instars has been known to occur in other insects under artificial rearing conditions. In any event, during the coming spring and early summer, we will be able to accept or reject the assumption through observation of the over-wintering larvae, now in hibernation.

PROJECT: Astronomical Polar Measurements of the Earth

STUDENT: **FRANKLIN F. WILCOX**, Grade 11

WINNER, Student Achievement Award, Future Scientists of America SCHOOL: Neodesha High School, Neodesha, Kansas

TEACHER: **DOROTHY VAUGHN**

[What are Earth's dimensions? For more than 2,000 years man has sought a precise answer. With modern instruments—the Vanguard satellite, for example—scientists have measured Earth's diameters down to a few feet. But in 250 B. C., a Greek mathematician, Eratosthenes, measured the Earth and found its circumference to be 25,000 miles—the value commonly used today. His instruments: a logical mind, the elements of plane geometry, and a simple instrument to measure angles.

Suppose that your math or science assignment for this year was to measure the Earth's polar circumference. Could you do it? Franklin Wilcox did.

Franklin's project emphasizes a most important idea, one we often forget—instruments are not science. They are merely useful extensions of the senses.]

FRANKLIN'S PROJECT

To carry out my project it was necessary to make two assumptions: one—that the Earth is a sphere, and two—that the surface has a fairly regular curve. The peculiarities in the orbit of the Vanguard satellite, Beta 1958, showed the Earth has a 50-foot depression around the South Pole, a 25-foot bulge near the south mid-latitudes, a 50-foot bulge around the North Pole, and a 25-foot depression around the north mid-latitudes.

These irregularities are so small compared to the size of the Earth, that they could not cause a measurable error in my results.

Two kinds of measurements are necessary to determine the size of the Earth—the angular and linear distances between two stations on Earth's surface.

The difficult manipulative problems in making the measurements required the help of another amateur astronomer.

We chose to use a star to determine our location in degrees of north latitude and compare the north-south linear distance with the angular difference of the star observed from two locations. Determination of the angular difference posed many problems.

We obtained a transit with a 25-power telescope to make our angular readings. On a trial observation with the transit we found that the cross hairs could not be seen unless they were illuminated. To overcome this difficulty we attached a "grain-of-wheat" bulb to the front of the transit's telescope.

To find the true altitude of a star, it was necessary only to observe the star's maximum altitude at the time it crosses a true north-south celestial line—the local meridian. We felt the project would be more complete if we pinned down the exact time a star crossed the meridian.

Because the altitude change of a star near the meridian is so slow, the exact time it crosses the meridian is very difficult to determine by direct observation. To obtain the correct time, I marked a sheet of graph paper so that the horizontal division represented two seconds and each vertical division represented one minute of an arc.

The position of a star was plotted by matching each altitude reading with its corresponding time. The exact time the star crossed the meridian was found with a possible error of a few seconds. Sirius was chosen for all observations. It is the brightest star, and the one most likely to be still visible in cloudy weather.

Star readings at the two locations could not be made simultaneously. Therefore, allowance was made for the time error caused by the Earth revolving around the sun. Stars are said to be in a given apparent celestial location three minutes and fifty-six seconds earlier each night. To prove this we clamped a small telescope firmly to a pipe on the side of a building. We found that the small telescope's cross hairs also had to be illuminated in order to see them. A tape recorder was set up to record the National Bureau of Standard's time tones from a short wave radio. When the star passed the cross hairs, I hit two pieces of metal together to record the exact time on the tape with the time tones.

This procedure was repeated the following night. Comparing the two readings we found a time difference of three minutes and fifty six seconds.

Finding the linear distance between the two stations also presented many problems.

North-South Line

We chose a section of highway extending from four miles north of Yates Center, Kansas, to a point forty-nine miles north at Lynden, Kansas.

Although correction could be made for most of the curves by driving on connecting side roads, there were two major problems in making the linear measurement. One was a bridge on a curve, with no side roads. The second, and most difficult, was the error in true linear measurement caused by hills.

The linear distance could be measured by a car speedometer to the nearest tenth of a mile. However, we wanted a more accurate method of measuring and some way to account for

jogs in the road. A revolution counter was attached by a rod and a flexible shaft to a speedometer. This device made one count for every revolution of the speedometer cable.

Next we calibrated the revolution counter against a measured distance. To do this we measured a mile along a very level section of highway with a 100-foot steel tape on February 5, 1959. We added five and one fourth inches for the slight shortening of the steel tape caused by the 55 degree temperature. (A chart obtained with the tape showed its lengths at different temperatures.) The revolution counter was checked against our measured mile and found to make 1,039 revolutions per mile at 40 miles per hour. This speed was used in all our measurements, so that errors from wheel slippage would be the same as on the calibrated mile.

Now that we could make linear measurements to the nearest five feet, the error caused by hills could be determined by using a fine army range finder. The error in the range finder was less than one per cent when checked against a known distance.

To find the hill error, we measured from the crest of one hill to the crest of another hill of approximately the same height. When a valley was approached, a counter reading, C_1, was taken. I marked the spot by tacking a sheet of white paper to a telephone pole or by noting some other object to which we could measure. Then we drove to the crest of the next hill and again noted the counter reading C_2. At this location, the range finder, which measures in yards, was set up and I measured the distance, D, back to the marked spot. Once we had a value for D, the method for making the corrections was quite simple.

Levelling the Hills

The error, E, caused by the valley between the hills was equal to the difference of the two counter readings, expressed in yards, minus the true distance measured with the range finder: $E = (C_2 - C_1) - D$. I used this method to measure the error of 18 valleys on our selected course.

By totaling the errors caused by the valleys and subtracting them from the final measurement, we found the true linear distance between the two observation stations to be 49 miles, 610 feet—or about 49.115 miles.

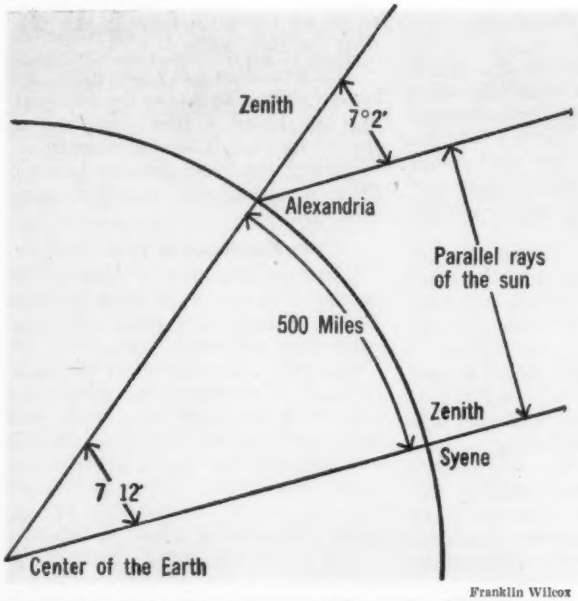
On March 7, 1959, we traveled to the south end of the measured line and set up the transit. I took altitude readings on Sirius and plotted it by the graph method as it crossed the meridian. The graph showed that Sirius crossed the meridian at 8:05:50 p. m., at an altitude above the southern horizon of 35 degrees 26 minutes.

Eight days later we traveled to the north observing point. I again observed and plotted Sirius as it crossed the meridian. I allowed for the 31 minute 28 second time difference caused by the star crossing the meridian 3 minutes and 56 seconds earlier each night. The graph showed that Sirius crossed the meridian at 7:34:07 p. m. at an altitude above the southern horizon of 34 degrees 43 minutes. The meridian crossing occurred 15 seconds earlier than was allowed by the time difference—the result of the north end of the selected highway being three and one half miles east of the south end.

The angular difference of Sirius between the two locations is 43 minutes —1/502.32 of the Earth's polar circumference. By multiplying the linear distance times the angular difference expressed in degrees of the Earth's circumference, we found the polar circumference of Earth to be 24,671 miles. Dividing the circumference by *pi* gave us 7,852 miles as the diameter of the Earth. These measurements are well within one per cent error according to the figures in the *World Almanac*, which gives the polar circumference as 24,860 miles and the polar diameter as 7,900 miles.

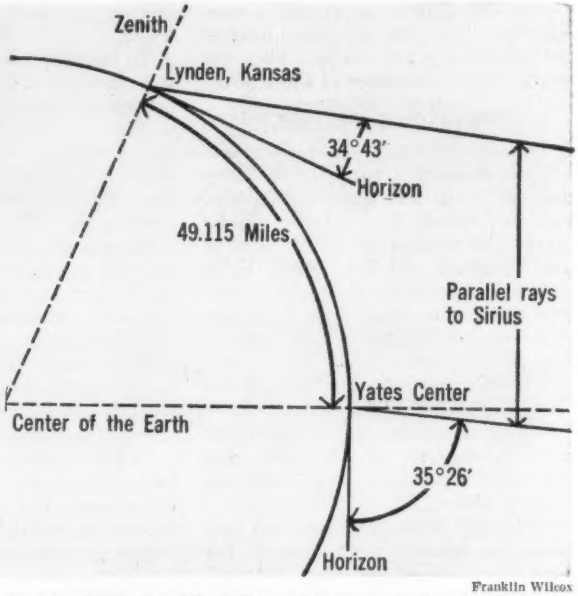
Considering the accuracy of our instruments, we feel our measurements are excellent.

This project has given me a much better concept of the Earth. I have learned how to operate many instruments and have gained valuable experience. After completing this project I can now see the possibilities of an astronomical equatorial measurement of the Earth, a project that interests me very much.



Franklin Wilcox

In 250 B.C., Eratosthenes measured the angle of the noonday sun at two Egyptian cities 500 miles apart. From angles and distance, he calculated Earth's circumference was 25,000 miles.



Franklin Wilcox

In A.D. 1959, Franklin Wilcox of Kansas, U. S., measured the angle of Sirius from the ends of a 49-mile line. From angles and distance, he calculated Earth's circumference as 24,671 miles.

By DR. ALEXANDER JOSEPH

PROJECT POINTERS

IN every issue, *Science World* will present a page of project pointers. Each pointer will be related to one of the major articles or features. You may wish to use the current crop to learn more about the principles of science, or to get started on a math or science project of your own. Perhaps you feel the need of a little "brain stretching" after the long vacation. The project on measuring molecules and the one on waves are guaranteed to provide plenty of "stretch."

Each of these project pointers explores some basic concept. While they are not projects in themselves, the concepts and techniques may suggest further ideas to get you started on a project of your own.

Measuring Molecules

You can measure the size of molecules. The Langmuir monolayer technique doesn't require special apparatus. You will need a large clean lunchroom tray, a half ounce of pure oleic acid from the drug store, two medicine droppers, ordinary rubbing alcohol, black paint, a 10 cc. graduate, a metric ruler and an ounce of old crankcase oil.

First paint the inside of the tray black. Do not use until absolutely dry. Then prepare your oleic acid mixture by dissolving one drop of oleic acid in 99 drops of alcohol. Next, calibrate your medicine droppers by counting the number of drops required to fill one cubic centimeter in the graduate.

Now pour water into the tray. On the water place one drop of the old crankcase oil. If you can not get old oil, use ordinary chalk dust dropped on the water by hitting two blackboard erasers together. Then drop one drop of the 1 per cent oleic acid solution (1 part of oleic acid to 99 parts of alcohol) on the water. A circular film will form. Measure diameter in centimeters.

The size of the molecule can be determined with the following formula for the volume of a cylinder:

Volume $= \pi r^2 h$, therefore $h = \frac{V}{\pi r^2}$

The amount of the oleic acid in the drop is 1/100 or 1 per cent of the drop. If the dropper delivers 30 drops per cc, each drop is 1/30 of a cc. You have 1/3000 cc. of oleic acid in each drop. This is equal to V in the equation. The value for π is 3.1416 and r^2 is the square of the radius of the circle of the monolayer film.

You have the diameter, thus ½ of that is the radius. Solving for h in the formula will give you the size of the oleic acid molecule.

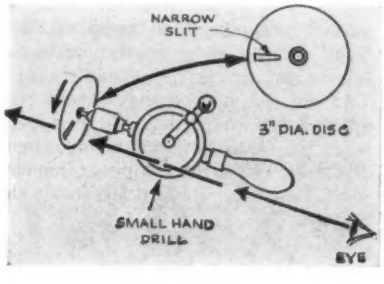
Now try ½ per cent oleic acid (one drop oleic acid to 199 drops of alcohol). After developing skill, try other esters and liquid proteins diluted to 1 per cent or less. Proteins will make star-shaped films. The area is found by dividing the star into triangles. If, in working with oleic acid, you find star-shaped films, you know that you have protein impurities—probably from your fingers.

Additional Starters

Investigate the thickness of thin oil films that give colors on water by diffraction. Note: Use oxidized (old) auto crankcase oil. Get the thickness from the wave length of the colors. Consult Physical Science Study Committee, *PHYSICS*, D. C. Heath. Part 2, last chapter.

Tsunami

To study the velocity, wave length and frequency of water waves in school or home laboratory, you need an old window frame with its glass. While it lies horizontally, supported by a stool in each corner, fill it with water. On the floor below, place white paper for a screen. Place a meterstick on the paper to measure wave length. Two feet above the "tank" (the window frame) place



a 150 watt, clear glass, straight filament light bulb with the filament vertical. Connect to house current. Generate waves in the water by rolling a length of broomstick back and forth slowly in the water. The wave images will be projected on the paper screen.

With the simple stroboscope (*see diagram*) time the waves and measure the wave length.

A bright bar is a crest, and a dark bar is a trough. A trough plus a crest make one wave length. To determine frequency, have someone time you for 15 seconds while you count the number of times you turn the crank of the strobe while holding the wave in apparent "stopped" motion. The gear ratio for the drill is the ratio of the number of teeth on the large gear to the number of teeth on the small gear. The gear ratio multiplied by the number of rotations of the handle is the number of waves in fifteen seconds. Divide by 15 to get the frequency (waves per second). The velocity is the wave length multiplied by the frequency.

Now you are ready to investigate the effect of depth of water upon velocity. You will need 1 inch of water in the tank. In the middle of the tank place a sheet of glass on supports so that the top is just 1 mm. under water. This creates a "shallow" spot. Repeat your experiments. Note change in wave length and velocity in shallow water.

Additional Starter

Using a deep tank (10") in which the water level can be changed by draining water, plot the relationship of water wave velocity to water depth for given wave lengths. Try to work out an equation for the curve you get.

Investigate the changes in wave properties that take place when oil, dust, etc. are placed on water.

Rocket Astronomy

Photograph the sun's corona by using a telescope to which you have added a black disk in the center to block out the sun's disk. The disk should be placed in the eye piece. Its size should be determined by the size of the sun's image as it appears on the ground glass of the camera. This makes your telescope and camera combination a *coronagraph*. WARNING: **Do not look at the sun directly through telescope.** If you take movies this way, you may photograph solar flares.

Additional Starter

Use a UV (ultraviolet) lamp to determine which transparent materials transmit ultraviolet light. Note: An electroscope charged positively is discharged by UV light.

U.S. MAIL LETTERS

Plant, Animal or _____?

Dear Editor:

A friend of mine told me that he read there were three kingdoms of living things. But I think that anything living must be either a plant or an animal. Who is right? If there is a third kingdom, what would it be?

Nancy Schriber
Trenton, New Jersey

Answer: Suppose you make two lists —one of all the black objects and the other of white objects. Blackness and whiteness are easily determined qualities that can be readily applied as standards. You would have no trouble with blackboards and new tennis balls, nor with white paint and black. But would a printed page be classified among the blacks or the whites? Or, would you pick it apart, and put the print with the blacks and the paper with the whites? This might be a solution, but it would forever eliminate the possibility of classifying printed pages and zebras —which have some blackness and some whiteness. You might decide to make a third classification—black and white.

Now let's divide all living organisms into two groups—plants and animals. Both have more characteristics in common than differences. But plants manufacture their food with the aid of chlorophyll and have cell walls of cellulose. And their freedom of movement is limited.

Animals are usually mobile or have a mobile stage. Most important of all, animals feed by ingesting (taking in) the products formed by plants—they do not manufacture food. You have no trouble telling puppies and poison ivy, or mosses and sea urchins, which may require careful examination.

But, as you work down toward the microscopic organisms, you find one that has chlorophyll but lacks a cell wall. Also it makes definite changes in location in response to stimuli. Its name is euglena. Plant or animal? There are many such organisms that defy exact classification. Another is a slime mold. Sometimes it appears plant-like and other times more like an animal.

The third kingdom, the Protista, is composed of organisms that do not clearly fit in either division. But remember—attaching a name is an arbitrary solution. It doesn't tell you what they *really* are.

Salt and Sweating

Dear Editor:

This summer I have been working in a warehouse that gets very hot. Sometimes it is as hot as 90 degrees. The foreman advises us to take salt pills. Why?

Gerald Sussman
Seattle, Washington

Answer: In this issue, the article, "Life of the Cell," states that a cell may be *thought* of as a kind of living chemical "factory." This, of course, is a figure of speech to emphasize the chemical basis of life. However, for the cell to carry out its chemical activities, balance must be maintained between water, the principal component of cells, and the slightly less than one per cent of mineral salts in the body fluids.

You take in salt with your food each day. So, to maintain the salt-water balance, salt must be excreted each day. The kidney bears the burden of salt excretion. Small amounts of salt are lost with the sweat, which amounts to a pint or so a day even when you are resting. But the sweat glands function as temperature controls, not as excretory (waste removal) organs.

Hard work raises the temperature of your body and perspiration increases accordingly. If the work takes place in a hot, enclosed room, sweating may increase to a point where the salt loss is considerable. You tend to drink more water which decreases the amount of salt in your blood still more. Since sodium—the mineral element in table salt—is a necessary component of the fluids that bathe the cells, you restore the salt-water balance by taking salt pills. The foreman's suggestion has a sound basis in science.

Bright Question

Dear Editor:

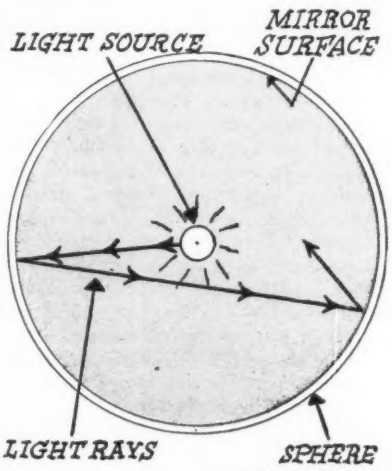
Suppose you have a mirror in the shape of a sphere, with the reflecting surface on the inside of the sphere. If a light were to shine briefly inside the sphere and then go out, would the light rays be trapped forever inside the sphere? Or would the light disappear when the source of light is extinguished? If the light does not disappear immediately, how long would it last inside the sphere?

Thomas Pliska
Van Nuys, California

Answer: Once the source of light is shut off, the light rays will continue to be reflected back and forth from the mirror surface of the sphere, but only for an extremely small fraction of a second. The reason for this is that no mirror is perfect; that is, no mirror reflects all the light which hits it. Every time a light ray hits a mirror surface, some of the light is trapped by the atoms near the surface and *absorbed*.

The best mirrors made today, such as those used in the giant astronomical telescopes, consist of a glass base coated with an extremely thin reflecting layer of aluminum. The aluminum film reflects, at best, only 98 per cent of the incident light. Every time the light is reflected, 2 per cent is lost by absorption.

Suppose our mirror sphere is one foot in diameter. We know that the speed of light is approximately 900,000,000 feet per second. Therefore, a light ray reflected back and forth from one side of the sphere to the other would be reflected 900 times in only one-millionth of a second. If 2 per cent of the light is lost at every reflection, almost all the light will have been absorbed after 900 reflections. This means that in one-millionth of a second the light would vanish almost completely. In fact, the light would vanish even more rapidly, for a number of additional reasons. Can you think of some of these reasons? Write us your answer. We will publish the best ones.



Science World graphic

Diagram illustrates effects of a light source contained inside mirrored sphere.

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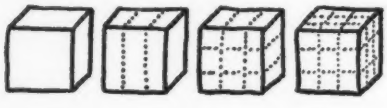
BRAIN TEASERS

Cube Cutter

With an ordinary buzz saw capable of making a straight plane cut, one can cut a solid cube of wood into 27 smaller cubes by making six cuts through the block, as follows:



However, it may be possible to do the same feat with fewer than 6 cuts, perhaps by restacking the pieces between cuts. Can this be done, or are six cuts the minimum?

Reed Gwillim Law, Jr.
Cortland, New York

Answer: Although many different arrangements of cuts and stacking of the pieces can be tried, it can be shown by simple logic that at least six cuts are required to make 27 cubes out of the large cube. Since the center cube has six plane faces inside the large cube of wood, a single cut of the buzz saw can fashion only one of these faces at a time. A total of at least six cuts is required.

Rock Crusher

In a country grocery store, a customer picks up a large rock that is lying on the counter and accidentally drops it. The rock crashes to the floor and breaks into four pieces. The grocer comes running and exclaims, "I have used that rock in weighing on my balance for 19 years. It will be difficult for me to replace it." However, the customer points out that the four pieces of rock would permit the grocer to weigh any object up to 40 pounds on his balance. What is the weight of *each* fragment?

David Drew
Cedartown, Georgia

Answer: Since up to 40 pounds can be weighed, the *total* weight of the four fragments must be 40 pounds. If the weights of the fragments are 1, 3, 9, and 27 pounds respectively, various combinations of these fragments on both sides of the balance will give a difference in weight ranging from one pound to 40. For example, five pounds of potatoes could be weighed by putting the nine pound fragment on one side of the balance and the one pound fragment, the three pound fragment, and the potatoes on the other side. This proves the customer is right.

Match Problem

Assume that a match is a unit of length. Is it possible, by using 12 identical matches (using the entire length of each match) to form the perimeter of a polygon with an area of exactly six square units?

Larry Morse
Pen Yan, N.Y.

Answer: The 12 matches can be used to form a 3-4-5 right triangle, as shown in the drawing. The area of this triangle is ½(3×4), or six square units. That the ratio of 3-4-5 forms a right triangle can easily be shown by using the Pythagorean theorem, where the sums of the squares of the two sides equals the square of the hypotenuse.

The Idol's Eye

An explorer was captured by some primitive natives, who worshipped an idol with jewelled eyes. In order to obtain his freedom, the explorer had to guess whether the idol's eyes were black or white, after being allowed to ask one and only one question. Of the 24 natives in the tribe, the explorer knew that 12 were liars and 12 told the truth. But he did not know which were which. After a great deal of thought, the explorer finally discovered the question which would solve his dilemma. What was it?

Richard A. Hazel
Norristown, Pa.

Answer: The explorer stood before the whole tribe and asked: "If I were to ask you what color are the idol's eyes, what would you answer?" All 24 natives answered "white." A little thought will show that the explorer's question is really made up of two questions: "What would you answer if asked the color of the idol's eyes?" and "what would you reply to the explorer concerning your answer?" The truth-telling natives would answer "white" to the first part, and "white" to the second part. The lying natives would answer "black" to the first part, and would reply "white" to the explorer, since they are habitual liars. Result? The explorer learned that the idol's eyes were white, and gained his freedom.

Ups and Downs

A hiker can average two miles per hour walking uphill and six miles per hour walking downhill. If he hikes up a hill and immediately comes back down by the same route, what is his average speed?

Ralph Staley
Sparta, New Jersey

Answer: The up and down distances are the same, but the time spent walking downhill is much less than the time spent walking uphill. Suppose the route from the bottom of a hill to the top of the hill is six miles long. The uphill climb would take three hours. The downhill walk takes one hour. This makes a total of 12 miles covered in four hours, an average speed of three miles per hour.

Send in Your Favorite Brain Teaser

You surely have a favorite brain teaser that you would like to share with other readers. Send the brain teaser, together with the solution, to Science World, *33 West 42nd Street, New York 36, N. Y. We will pay $5 for every brain teaser published. Include the name of your school, in addition to your home address, and state your age.*

Answers to Crossword Puzzle

(See page 31)

■	O	X	I	D	E	■	A	L	L	O	Y	■
H	■	E	L	M	■	M	■	B	A	S	■	C
A	M	■	L	■	F	E	O	■	W	■	O	H
B	A	D	■	N	I	T	R	O	■	F	H	A
E	R	■	B	■	R	A	G	■	G	■	M	L
R	■	E	R	A	■	L	■	G	A	S	■	K
■	G	R	I	N	D	■	R	O	M	A	N	■
I	■	E	N	D	■	S	■	A	M	P	■	U
N	B	■	E	■	M	O	L	■	A	■	B	I
E	A	R	■	H	E	L	I	X	■	R	O	D
R	N	■	C	■	V	I	E	■	A	■	W	E
T	■	D	O	N	■	D	■	D	I	P	■	O
■	A	L	G	A	E	■	B	O	R	A	X	■

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Signal Oscillator, Key and Flasher . . . the complete outfit to learn to receive and transmit the Morse Code . . . the first step to a Ham License.

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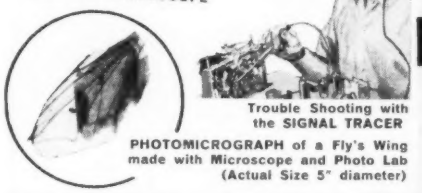

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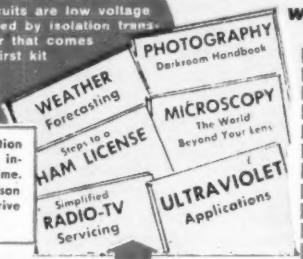

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Rocket Astronomer

(Continued from page 20)

was fired by radio command from the ship.

In ten attempts, Dr. Friedman managed to catch only one small flare. This sketchy result, however, did indicate a major increase in X-ray radiation in the ionosphere at the time of the flare.

In 1957, at San Nicolas Island, off the coast of California, another group from the Naval Research Laboratory succeeded in getting a number of rockets into the air minutes after a flare. Again the results showed evidence of an increase of X ray radiation in the ionosphere.

"A funny thing about this work," Dr. Friedman recalled, "is that after trying several attempts to shoot into flares, we got our best results on a flare when we were trying to do something different.

"We were out in the vicinity of the Danger Islands of the South Pacific, in 1958, preparing to make X-ray and ultraviolet measurements of a solar eclipse, scheduled for October 12, 1958. We knew from astronomical predictions that a total eclipse of the sun would be visible for four minutes from the small island of Puka Puka."

Six Rockets—and a Theory

The experiment was designed to measure X-ray and ultraviolet emissions from the sun as the shadow of the moon progressed along its path. Any radiation detected by the instruments would be emitted from the portions of the sun not blocked out by the moon. At totality (the point when the moon completely obscures the sun) the entire disk would be shielded. Any radiation then would be coming from the sun's outer rim, the corona.

Aboard the U.S.S. *Point Defiance*, six Nike-Asp solid propellant rockets were in position, ready to be launched.

Dr. Friedman planned to launch two of these rockets during totality. The other four shots were scheduled to measure radiation as portions of the disk were exposed at various times before and after totality.

The first four rockets were fired exactly on schedule. However, mechanical trouble caused a delay in the fifth firing. It didn't get off until the time when the sixth rocket should have been sent up. Since there was little to gain by firing the last one, Dr. Friedman decided to hold it for the next day.

"These experiments gave us the most beautiful confirmation of our present theories of where radiations originate on the sun," Dr. Friedman explained. "When the disk was completely blocked off, the ultraviolet light disappeared almost completely, showing that it comes from the disk area. But the X rays were only slightly diminished. The only place they could come from then is outside the eclipsed disk—from the corona."

The sixth rocket was fired the next day. To Dr. Friedman's delight, it coincided exactly with a spectacular flare on the sun. During the rocket's eight-minute ride the scientists were able to get accurate measurements of the radiation emitted during the flare.

"We got perhaps the most interesting flare data that we've ever gotten without planning it that way," Dr. Friedman recalled. "We know now, conclusively, that a solar flare produces a brilliant flash of X rays and not ultraviolet light, as we used to think. It is these X rays that disrupt our ionosphere and produce radio fadeouts."

Briefing Tomorrow's Scientists

Though he left the study of art for study of the universe, Dr. Friedman still finds his relaxation among sketch pads and charcoal. His love for art once caused a commotion at the White Sands Proving Grounds, while he was doing research there. Early on a Sunday morning, he was spotted by a security guard in a restricted area. There was no need for alarm, though. Dr. Friedman was only sketching the mountains.

In addition to his sketching, Dr. Friedman enjoys listening to classical music from his extensive record collection. He lives with his wife and two sons, Paul, 16, and Jon, 13, in Arlington, Virginia.

Once a year, Dr. Friedman goes to school with his sons and talks to their classmates on science topics. It is a briefing session he always looks forward to. Engaged in study of the universe, Dr. Friedman has not forgotten that the important research of tomorrow will be done by the students of today.

—Frances Gudemann

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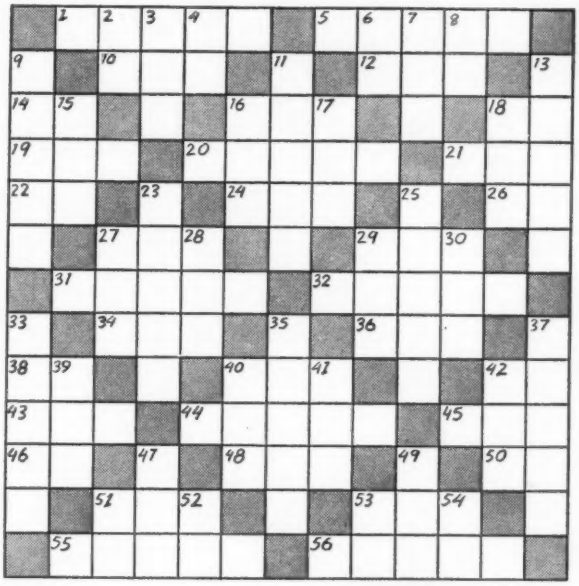
Exploring the Elements

By Karen Helmes, St. Francis de Sales High School, Utica, N. Y.

★ Starred words refer to the elements

Students are invited to submit original crossword puzzles for publication in *Science World*. Each puzzle should be built around one topic in science, such as astronomy, botany, geology, space, electronics, famous scientists, etc. Maximum about 50 words, of which at least 10 must be related to the theme. For each puzzle published we will pay $10. Entries must include symmetrical puzzle design, definitions, answers on separate sheets, design with answers filled in, and statement by student that the puzzle is original and his own work. Keep a copy as puzzles cannot be returned. Give name, address, school, and grade. Address Puzzle Editor, Science World, 33 West 42nd Street, New York 36, New York. Answers to this puzzle are on page 28.



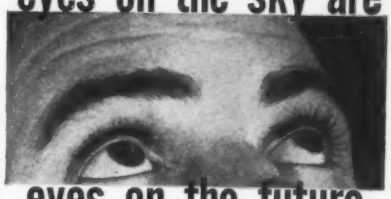
ACROSS

° 1. Compound of oxygen and another element.
° 5. Fused mixture of two or more metals.
10. Shade tree of genus *Ulmus*.
°12. Barium Sulfide (*chemical formula*).
14. Before noon (*abbr.*).
°16. Iron rust (*chemical formula*).
18. Exclamation of surprise.
19. Not good.
°20. Certain compounds of nitrogen.
21. Federal Housing Administration (*abbr.*).
°22. Rare-earth metal, atomic No. 68 (*chemical symbol*).
24. Shred of cloth.
°26. One-thousandth of a liter (*abbr.*).
27. Period of time from an event.
°29. Matter in vaporous state.
31. Reduce to powder by mechanical method.
32. Native of Rome.
34. Finish.
36. Ampere (*abbr.*).
°38. Element formerly named columbium (*chemical symbol*).
°40. One gram-molecular weight of a substance (*abbr.*).
°42. Bismuth (*chemical symbol*).
43. Organ of hearing.
°44. Wound in a spiral coil.
45. Slender bar.
°46. Radon (*chemical symbol*).
48. Strive or contend for superiority.
50. _____ are, you are, they are.
51. Spanish nobleman.
°53. Magnetic inclination.
55. Simple plants that grow in ponds, rivers, oceans, and the soil.
°56. Another name for sodium tetraborate.

DOWN

° 2. Atomic No. 54 (*chemical symbol*).
3. Sick.
° 4. One tenth of a meter (*abbr.*).
6. Pound (*abbr.*).
° 7. Gay-Lussac's _____ formulates combining gas volumes.
° 8. Osmium (*chemical symbol*).
° 9. Scientist who invented process for synthesizing ammonia.
°11. An element which "lends" electrons is usually a _____.
°13. Common name for a form of calcium carbonate.
15. Spoils or damage.
16. Coniferous tree.
°17. Organic (*abbr.*).
18. Unit to measure electrical resistance.
°23. Concentrated aqueous sodium chloride solution.
°25. High energy radiation, _____ rays.
27. Before (*poetic*).
28. *The Old Man _____ the Sea.*
29. Portuguese territory in India.
30. Juice of plants.
°33. Nonreactive gases are called _____.
°35. A state of matter which has definite volume and definite shape.
37. Television.
39. Forbid or prohibit.
°40. Million electron volts (*abbr.*).
41. Falsehood.
42. Forepart of a boat or ship.
47. Toothlike projection on rim of wheel.
°49. Mixture of gases surrounding Earth.
51. Decilitec (*abbr.*).
°52. Natrium (*chemical symbol*).
53. Perform an action.
°54. Protactinium (*chemical symbol*).

eyes on the sky are



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Using Science World in Your Teaching

The Life of the Cell (pp. 5-8)

Biology Topics: The structure of cells—microscopic and ultramicroscopic; metabolism within cells; functions of cell parts; mitosis

Chemistry Topics: Organic Chemistry

About This Article

The structure and physiology of cells are described on three levels of penetration—the microscopic, the ultramicroscopic, and the biochemical. This article will take any of your students as far as he can go in the study of cells, carrying him from the ordinary observations possible in the classroom to the most recent revelations of the research laboratory.

After reviewing the structure of the cell as depicted in most standard textbooks, the author goes on to describe the work of several leading investigators engaged in exploring the cell with the aid of such modern devices as the electron microscope and the ultra-centrifuge. Much of the work described goes beyond the observational to the experimental. It involves such ingenious operations as getting genetic material out of bacteria or using a specific enzyme to dissolve the cell wall of bacterial cells. Such studies extend our knowledge of the functions of microsomes, mitochondria, and many "boundaries" we call membranes, including the cell membrane itself. Even the cell wall, it appears, has more than a protective function, at least in the yeast cell.

To give you some idea of the scope of this article and its coverage of "content," here are some of the cellular structures to which the article refers: nucleus, nucleolus, cytoplasm, cell membrane, cell wall, chromosome, mitochondria, and the nucleic acids (RNA and DNA). Among the cellular "activities" noted are the uncoiling and separation of nucleic acid molecules, interchange of materials between nucleus and cytoplasm, and the role of enzymes.

Topics for Class Discussion

1. "The key chemical component of each chromosome is DNA."

a. Where in a cell would DNA be found?

b. Where in a cell would RNA be found?

c. Where in a cell would RNA be concentrated?

d. What is the shape of DNA?
e. How may DNA be removed from a cell?
f. What evidence is there that DNA may "replicate" itself?
g. What evidence is there that DNA may influence the characteristics of bacteria?
h. What evidence is there that in any cell, nucleic acids may pass through the nuclear membrane?

2. Describe the membrane of a mitochondrion (singular of *mitochondria*).

3. Describe the nuclear membrane in action.

Books that will enable your students to explore further:

R. W. Gerard, *Unresting Cells*

I. Asimov, *The Chemicals of Life*

And a book for "teacher": Arthur C. Giese, *Cell Physiology*

Tsunami (pp. 9-12)

Physics Topics: The nature and propagation of waves; kinetic energy; effects of radioactivity

Earth Science Topics: The structure of the Earth; evolution of the Earth; seismology

Vocational Guidance: Geophysics

About This Article

A tsunami is a "mountain" of energy moving through water at jet plane speeds, causing the water to smash into islands and continents, leaving death, havoc, and destruction in its wake. Tsunamis were dramatically described by newspapermen last spring after the series of tidal waves that hit places as far away from each other as Chile and Japan.

What the author does is to take a hard look at a tsunami from the point of view of a geophysicist. To help understand the origin of a tsunami, he describes the structure of the Earth inferred from seismological evide In his description, the author calls sp cial attention to a recently discover feature of the Earth's structure, name the *Mohorovicic discontinuity*, a reg between the Earth's crust and its ma tle. To explain the nature and mov ment of a tsunami, the author ente into a lucid discussion of wave defining and explaining length, amp tude, frequency, velocity, and period ity. He gives the relationship betwe the velocity of the tsunamis and t depth of the water in which they trav "In 30,000 feet of water, they hit 6 mph." Finally, the author describes t world-wide warning system designed minimize the damage from these drea ful visitations.

Topics for Class Reports and Discussio

1. Describe the core, mantle, a crust of the Earth, presenting a theo on how these came to be located whe they are.

2. Explain how the *Mohorovicic d continuity* was discovered and how it being explored at the present time.

3. Present a theory to account f how a tsunami originates and cite so evidence that supports this theory.

4. Define each of these terms appli to waves: wave length, amplitude, fr quency, velocity, periodicity.

5. Discuss the wave lengths, amp tudes, frequencies, velocities, and pe odicities of tsunamis.

6. Describe the world-wide tsuna warning system.

Building Blocks of Matter (pp. 13-16)

Chemistry Topics: Atoms and mo cules; the periodic table of eleme

Physics Topics: X-ray diffraction; Brownian movement; kinetic theory; mensuration; Newton's laws

About This Article

The concepts of "elements" and that of the "atom" are traced from the abstractions that they were in the minds of ancient Greek philosophers to the very real things they are in the minds of physicists and chemists today. The author describes the studies by which scientists arrived at present-day concepts of the atom. The article does not, however, deal with nuclear particles and their arrangement within the atom. These are left to a future article.

Questions for Review

1. Distinguish between these terms: atom, element, molecule.
2. Contrast Dalton's idea of the atom with the present-day idea of the atom.
3. How was the ancient idea of "four fundamental elements" disproved?
4. What was Mendeleyev's contribution to our understanding of elements?
5. How are the sizes of gas molecules determined? of liquid and solid molecules?
6. Describe the present-day use of computers in studying atoms.

Today's Scientists (p. 20)

Dr. Herbert Friedman—Rocket Astronomer

Physics Topics: Radiations from the sun; rocket astronomy; the Earth's ionosphere; solar flares

Vocational Guidance: Astrophysicist

About This Article

Here is a brief biography of Dr. Herbert Friedman, who developed instruments suitable for use in rocketry with which to study the radiations emanating from astronomical bodies. The article describes studies revealing for the first time that ultraviolet radiations coming from the sun originate mostly in the sun's surface, while X rays come from its corona. Included, too, is the story of how Dr. Friedman found that X rays from solar flares are responsible for disturbances in the Earth's ionosphere.

Suggested Approach in Introducing This Article to a Class

Imagine that we all live at the bottom of the sea instead of the bottom of an ocean of air. Those of us who lived at great depths would hardly be aware of the sun, moon, or stars because their light would be absorbed by the water before it could reach us. Those who climbed the undersea mountains might become aware of the astronomical bodies, but would see them dimly.

We who *do* live in air are in a somewhat comparable position so far as the sun is concerned. Much of the sun's radiation is absorbed by the ocean of air above us. Much of the ultraviolet radiations, in particular, are absorbed. Then there are radiations of much shorter wave lengths than ultraviolet rays. These hardly get through the atmosphere at all. This is true of X rays coming from the sun.

Two recent products of science now make it possible more adequately to study the sun's radiations: (1) rockets that can travel higher in the atmosphere than man himself can go; (2) instruments that are able to detect various kinds of radiations and communicate the information to man down on the Earth. The study of astronomical bodies by means of instruments carried up in the air by rockets is called *Rocket Astronomy*. This article is about the man who developed these instruments and who is pioneering in this field of science.

Tomorrow's Scientists (pp. 21-24)

Life History of *Euptychia Mitchellii*

Two high school students report on observations by which they succeeded in unraveling the hitherto undescribed life history of a specific butterfly. This butterfly they studied is rather inconspicuous and lives in only a few secluded places in southern Michigan and nearby Indiana. A female of this species was collected and placed under conditions that induced her to lay eggs. The students closely observed the hatching of the eggs and they followed the development of a succession of instars through pupation to adulthood.

Teaching Suggestion

At the beginning of the school year, many biology teachers make it a practice to call attention to the need for meticulous observation in any scientific work. They also call attention to the opportunities for individual or group project work during the school year.

The report of Stephen Hubbell and Thomas Pliske can serve as an excellent example of meticulous observation. Attention might well be called to the *quantitative* nature of the set of "rearing notes."

Another significant feature of this project is worthy of attention: a really significant piece of work was carried out with little more equipment than a pencil, a magnifying glass, a ruler, a watch, and a calendar. This should serve to dispel the notion that to do any project work in biology requires expensive and elaborate equipment.

Polar Measurements of the Earth

Somewhere near the beginning of the physics course, a discussion of measurement and mathematics in relation to physics is desirable. Franklin's project may serve as an interesting and concrete example of measurement and the application of mathematics to the solution of a clearcut problem—to determine the Earth's polar circumference.

In solving this problem Franklin used relatively simple equipment. What he did was this: he measured the *linear* distance between two cities in Kansas —two cities that are on a north-south line and connected by a highway running north-south. Then he measured the *angular* distance between these two cities, making use of a transit to determine the altitude of the star Sirius. Knowing the linear and angular distances between the two "points," he calculated the polar circumference of the Earth.

Sounds simple. But think of the *correction* factors involved. In measuring the linear distance between the cities, Franklin had to take into account the auto road running up and down hills and valleys. In taking his star altitude measurements, he had to consider the moving Earth. It is in being aware of these sources of error and in inventing ways of determining correction that this young man showed real ingenuity.

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